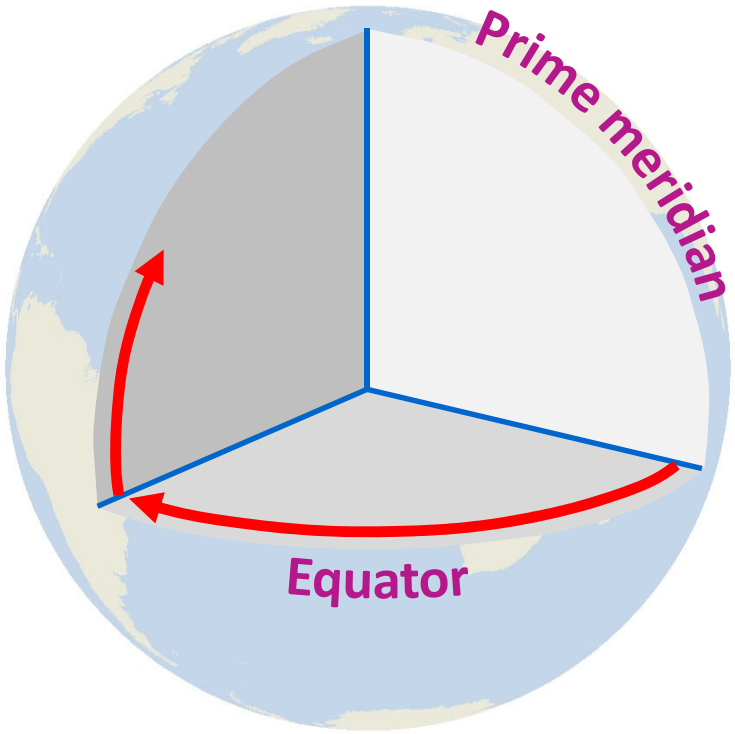
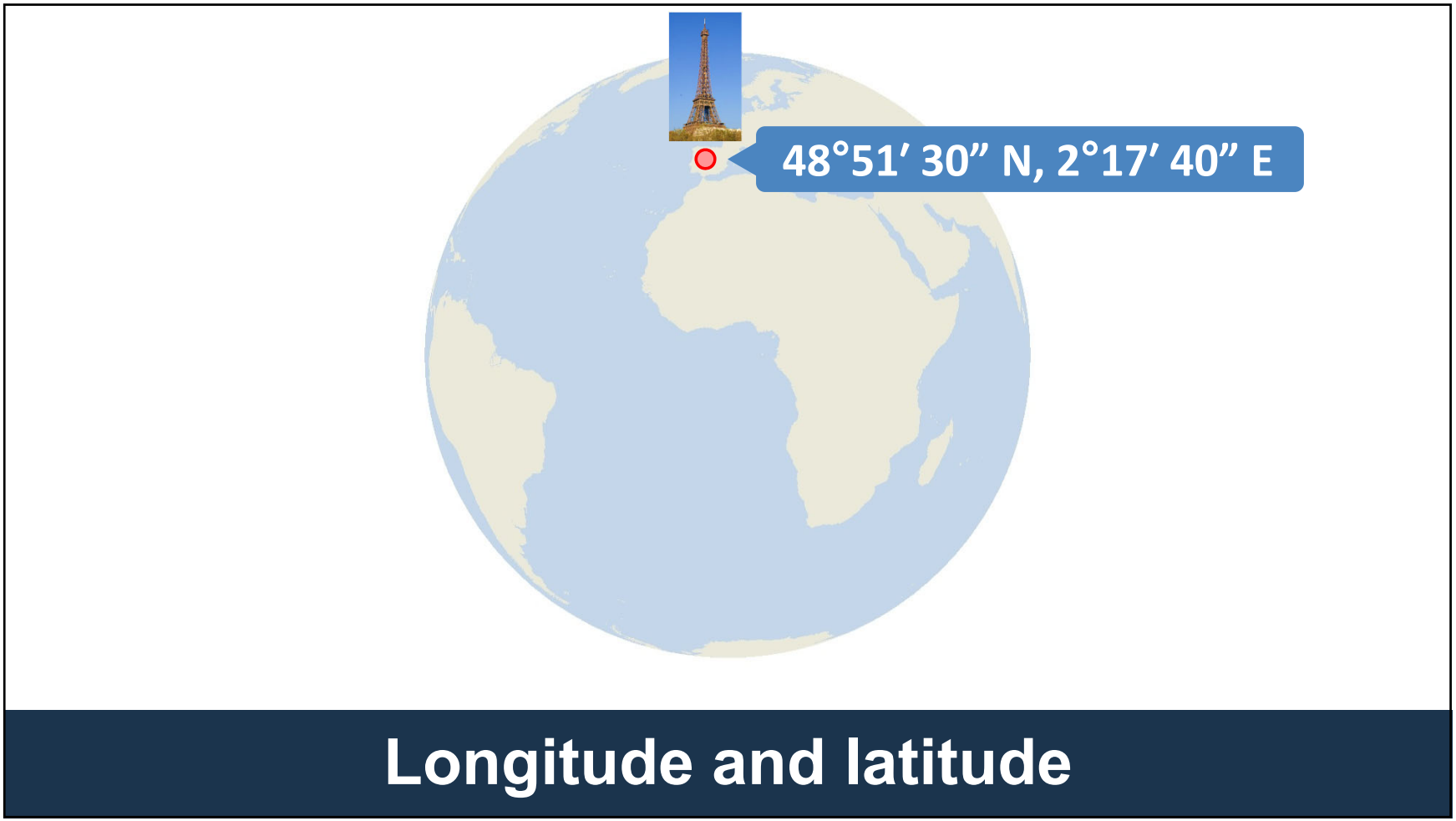
Longitude and latitude

How do we describe a location?

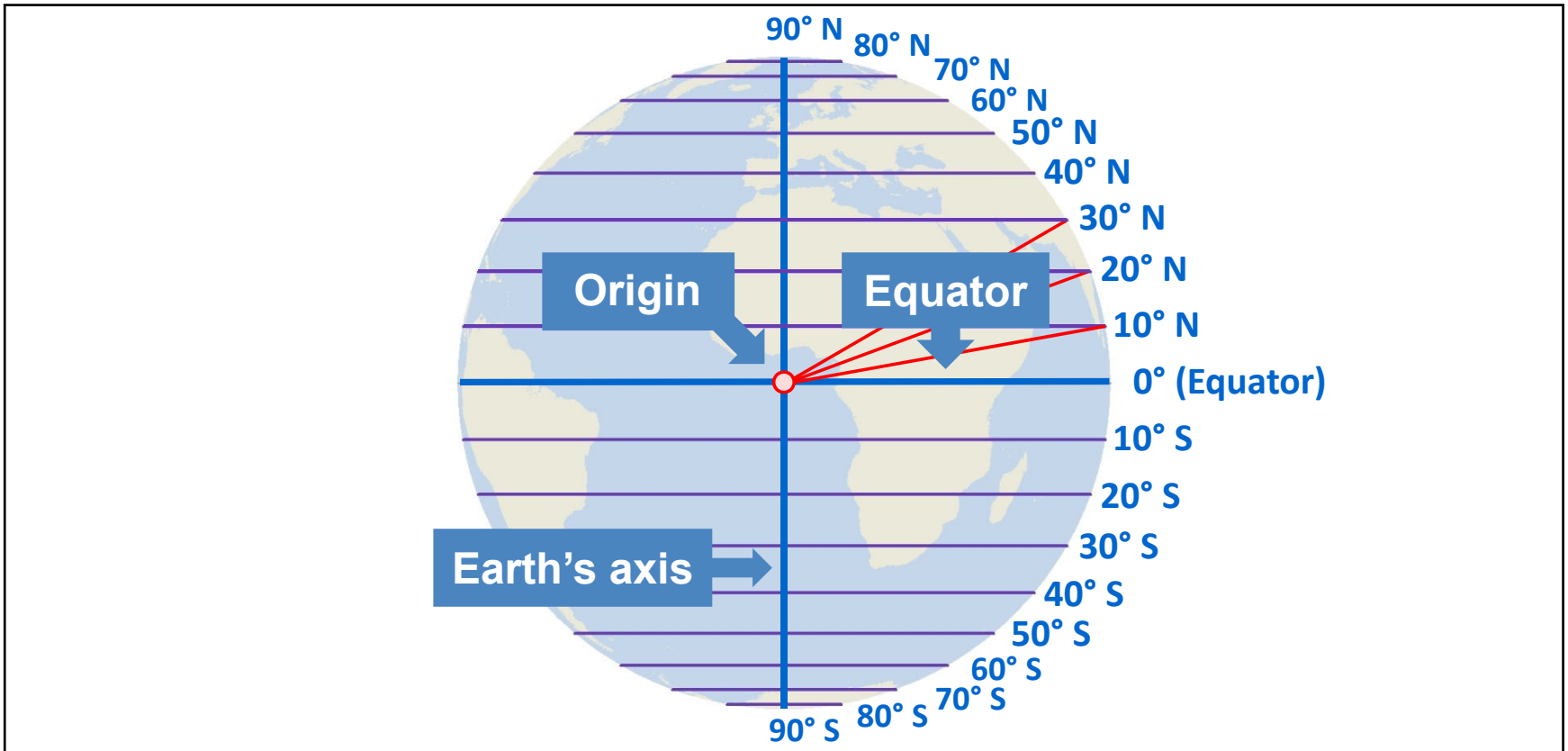


(adapted from Kimmerling *et al.*, 2009)

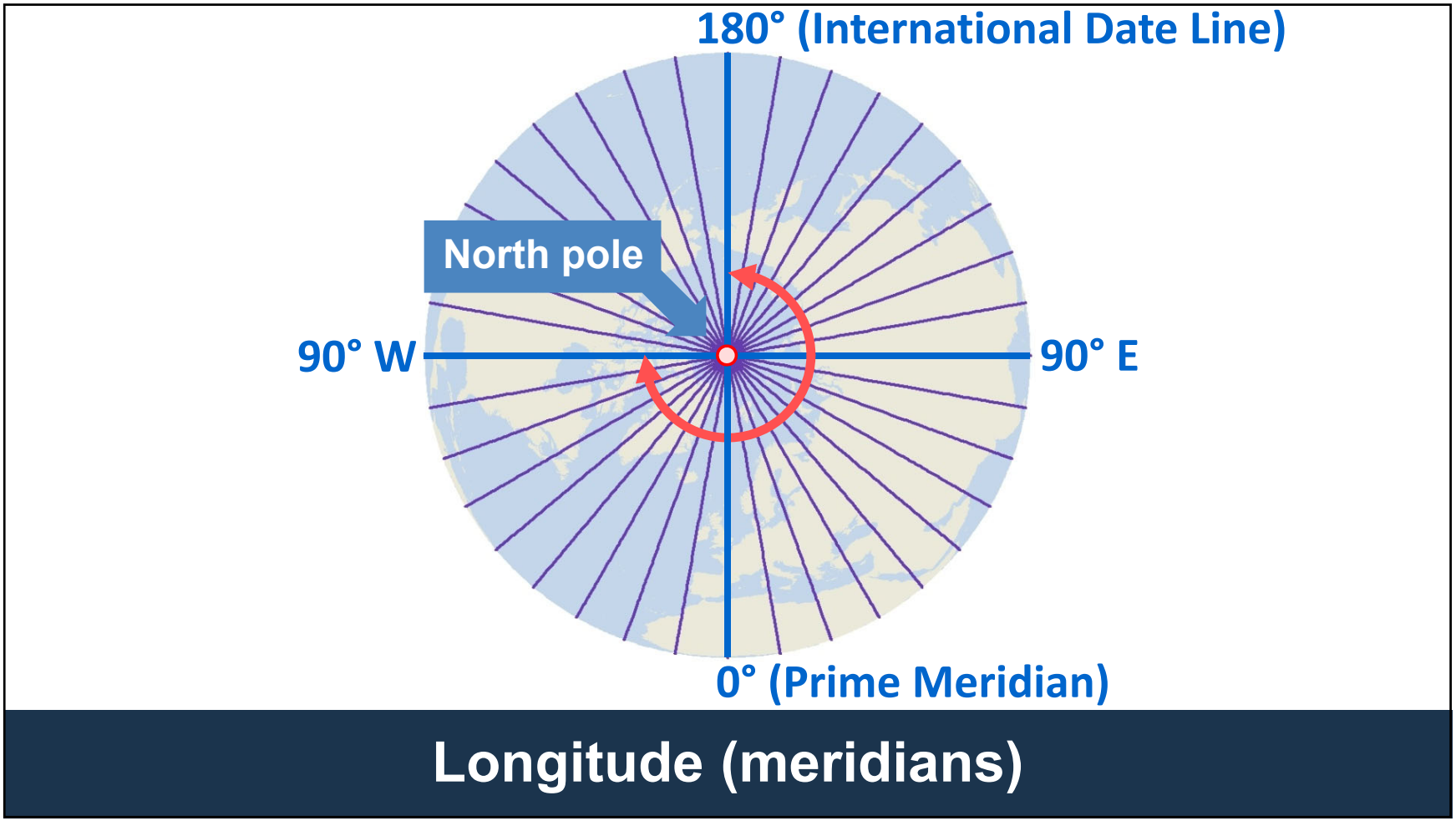
Angular unit of measure



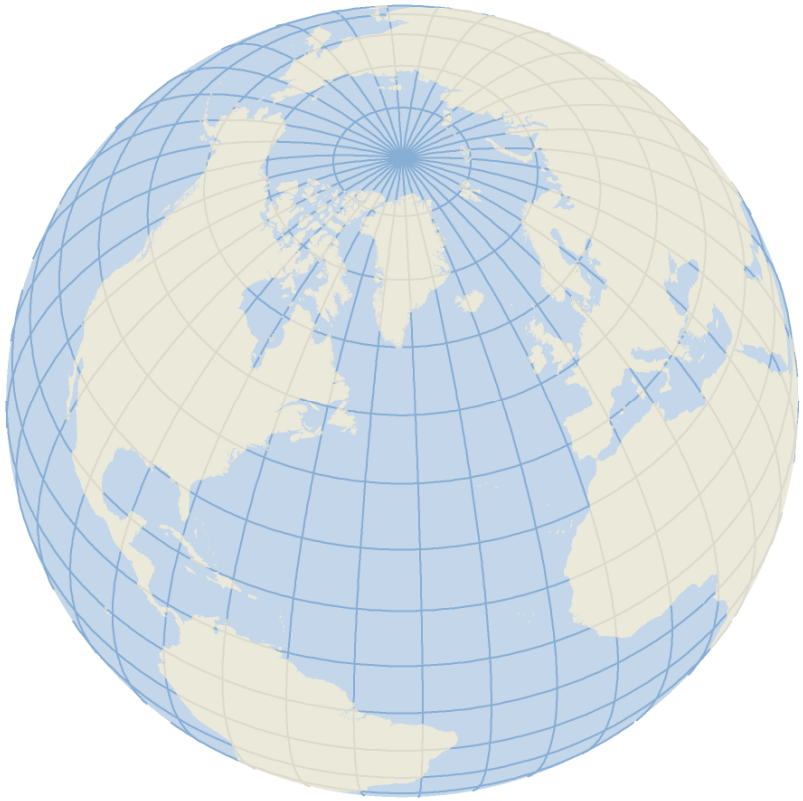
Longitude and latitude



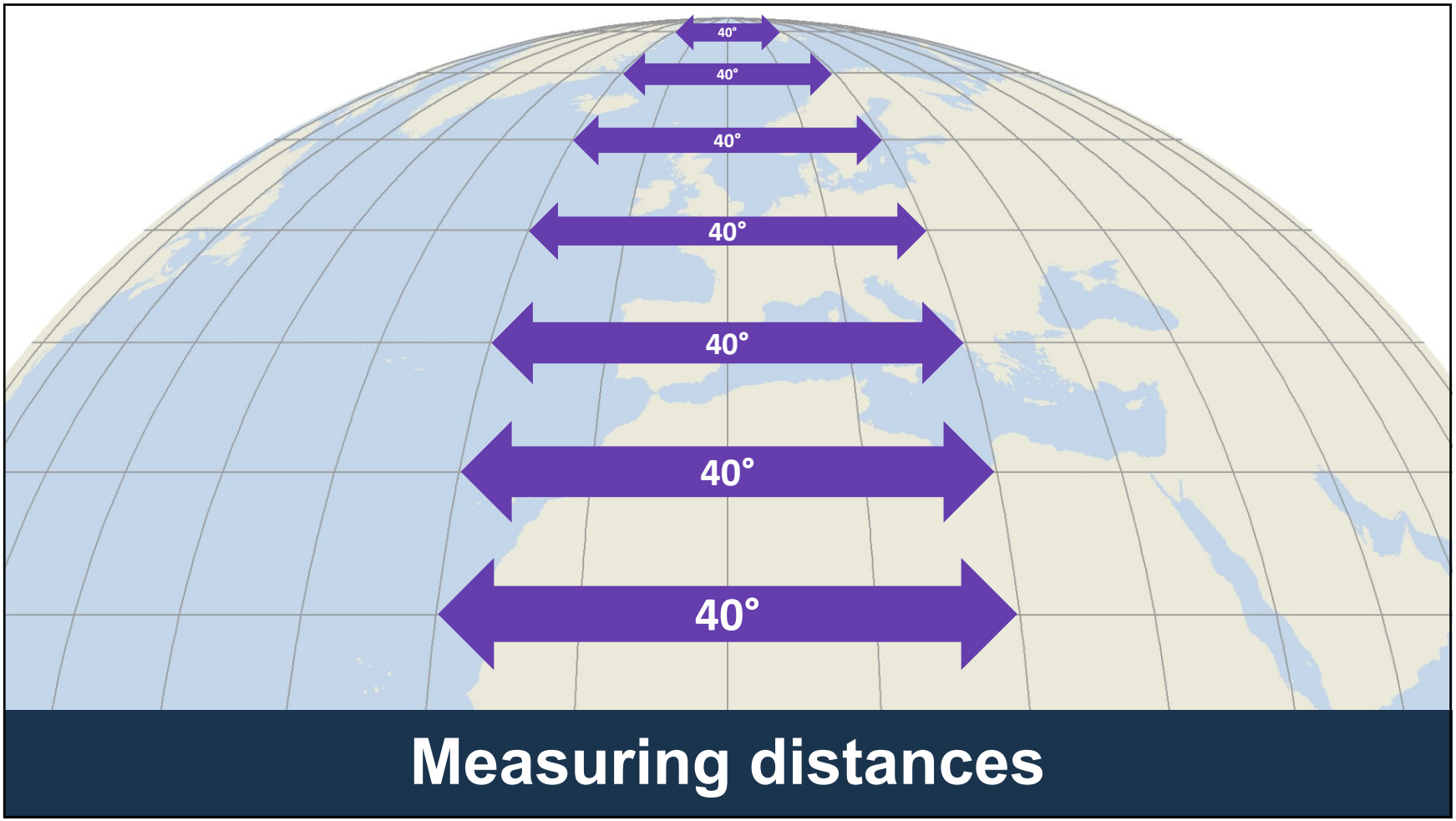
Latitude (parallels)



Longitude (meridians)

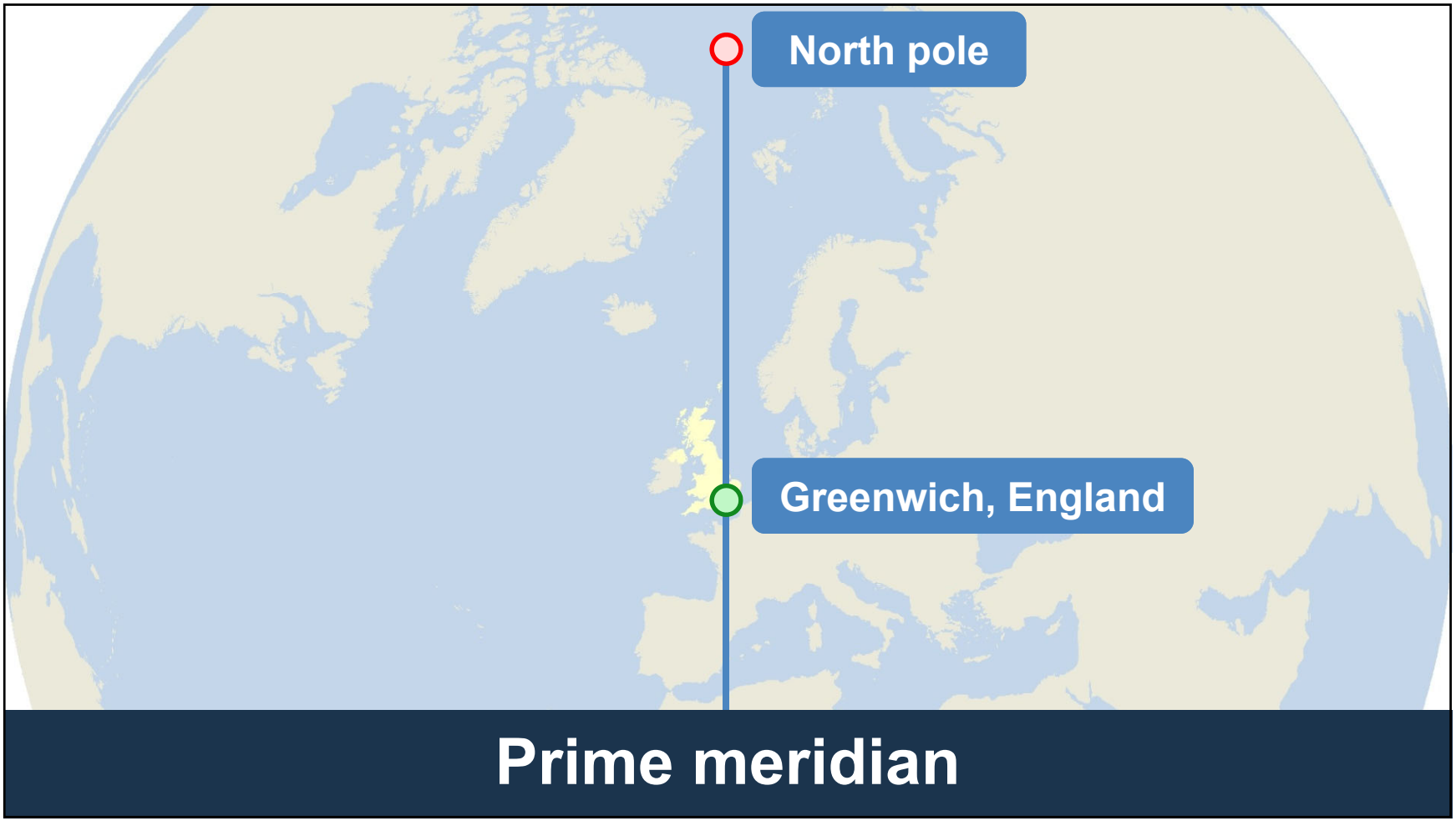


Graticule



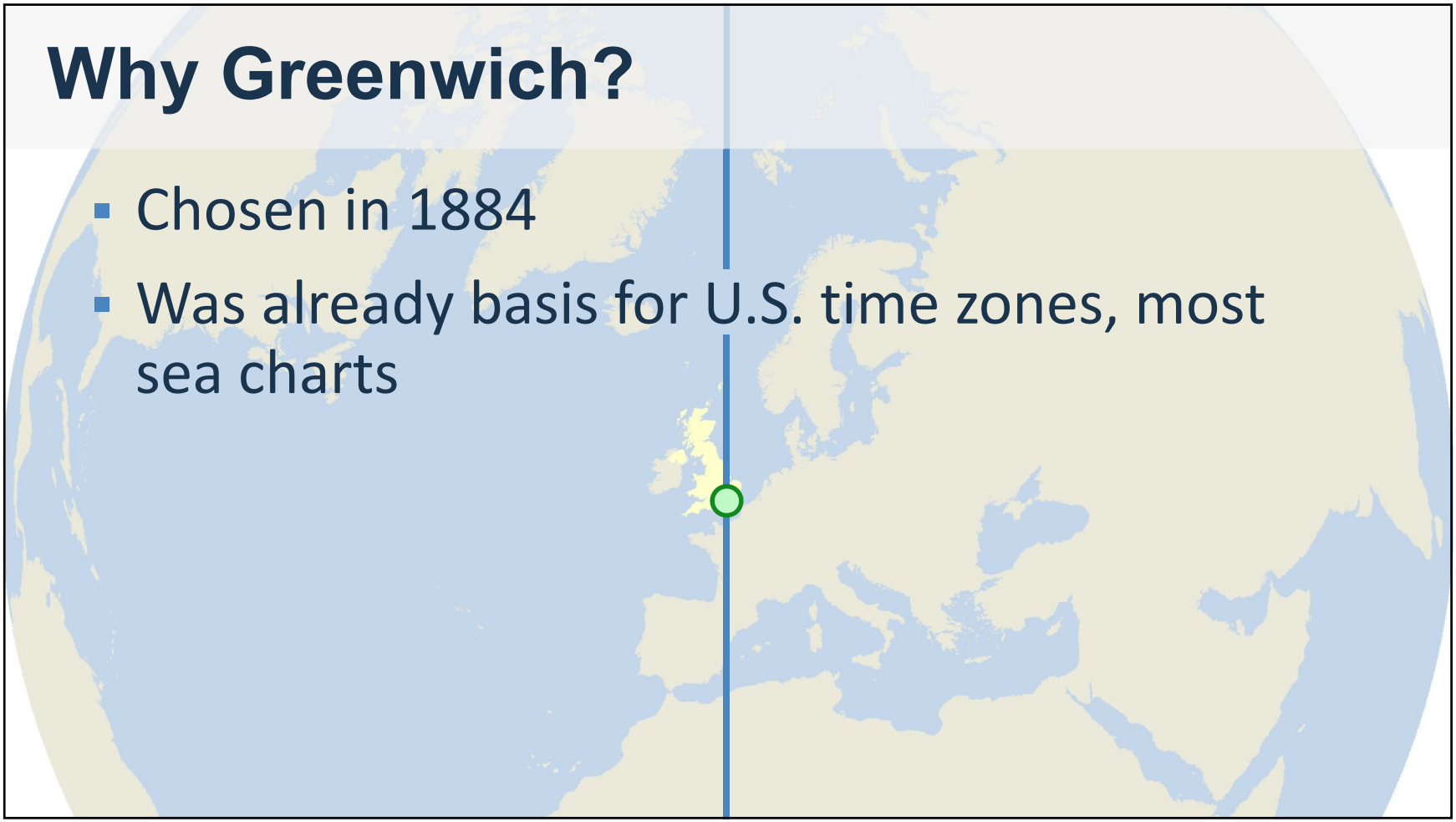
Measuring distances

Defining the prime meridian



Why Greenwich?

- Chosen in 1884
- Was already basis for U.S. time zones, most sea charts



Where in Greenwich?

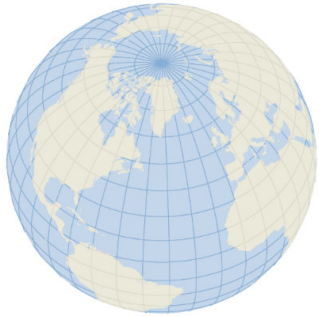
Photomechanical print after Lock & Whitfield

Airy Transit Circle

Where in the Observatory?

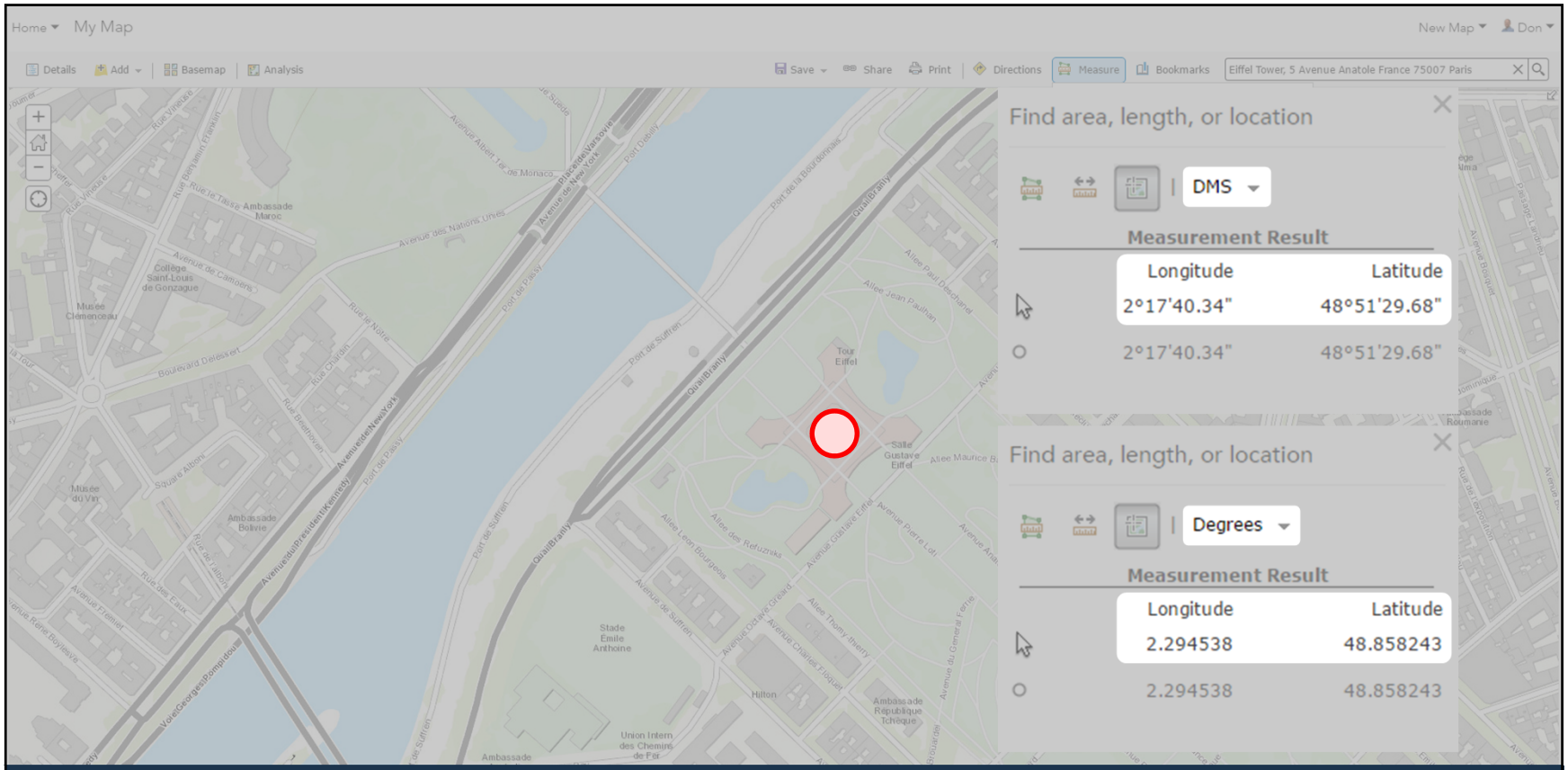
Long/Lat Coordinates

- Sexagesimal (base 60) system
- Degrees, Minutes, Seconds (DMS)
  - e.g. 142° 32’ 23”

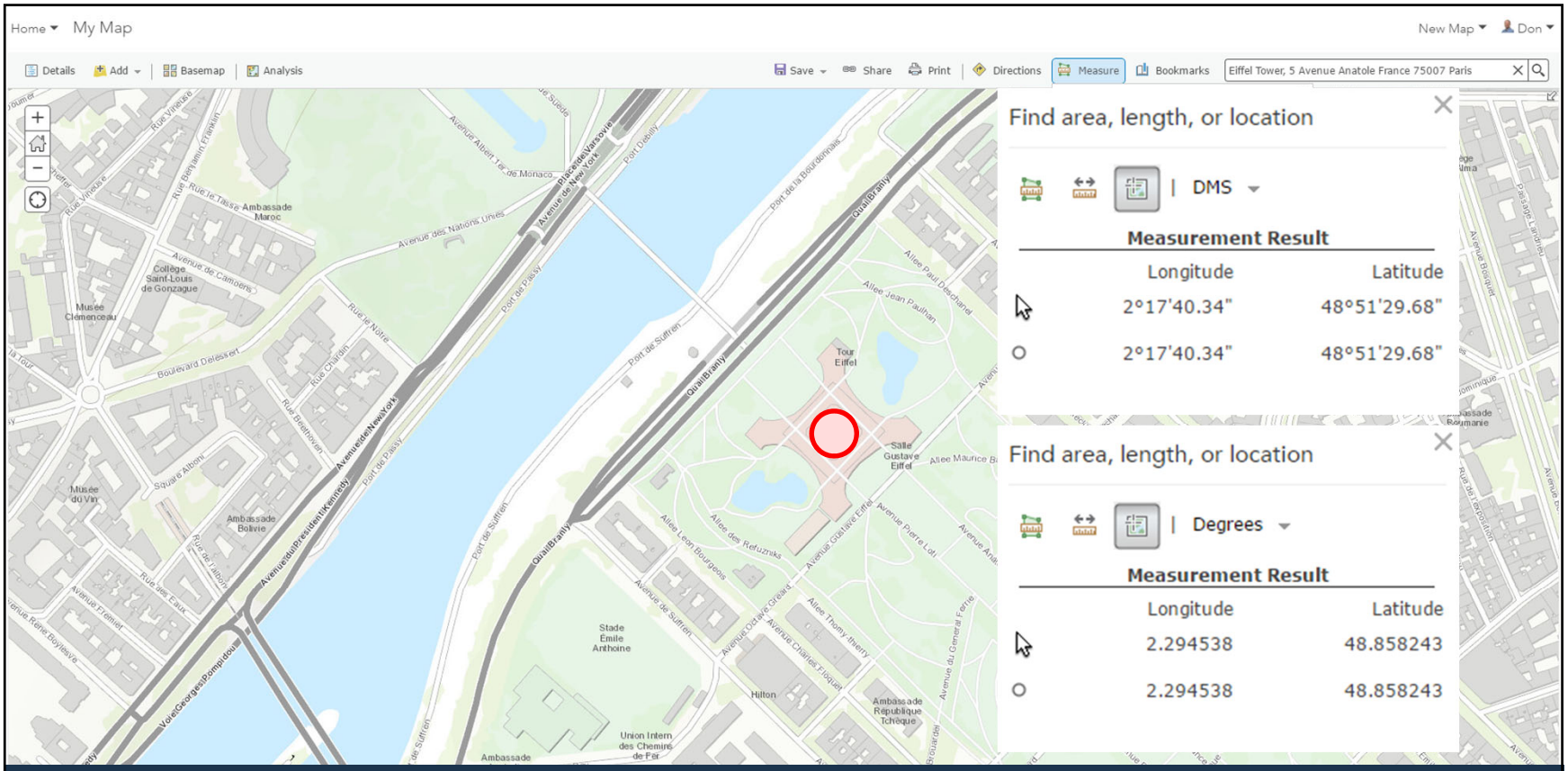


1 degree = 60 minutes

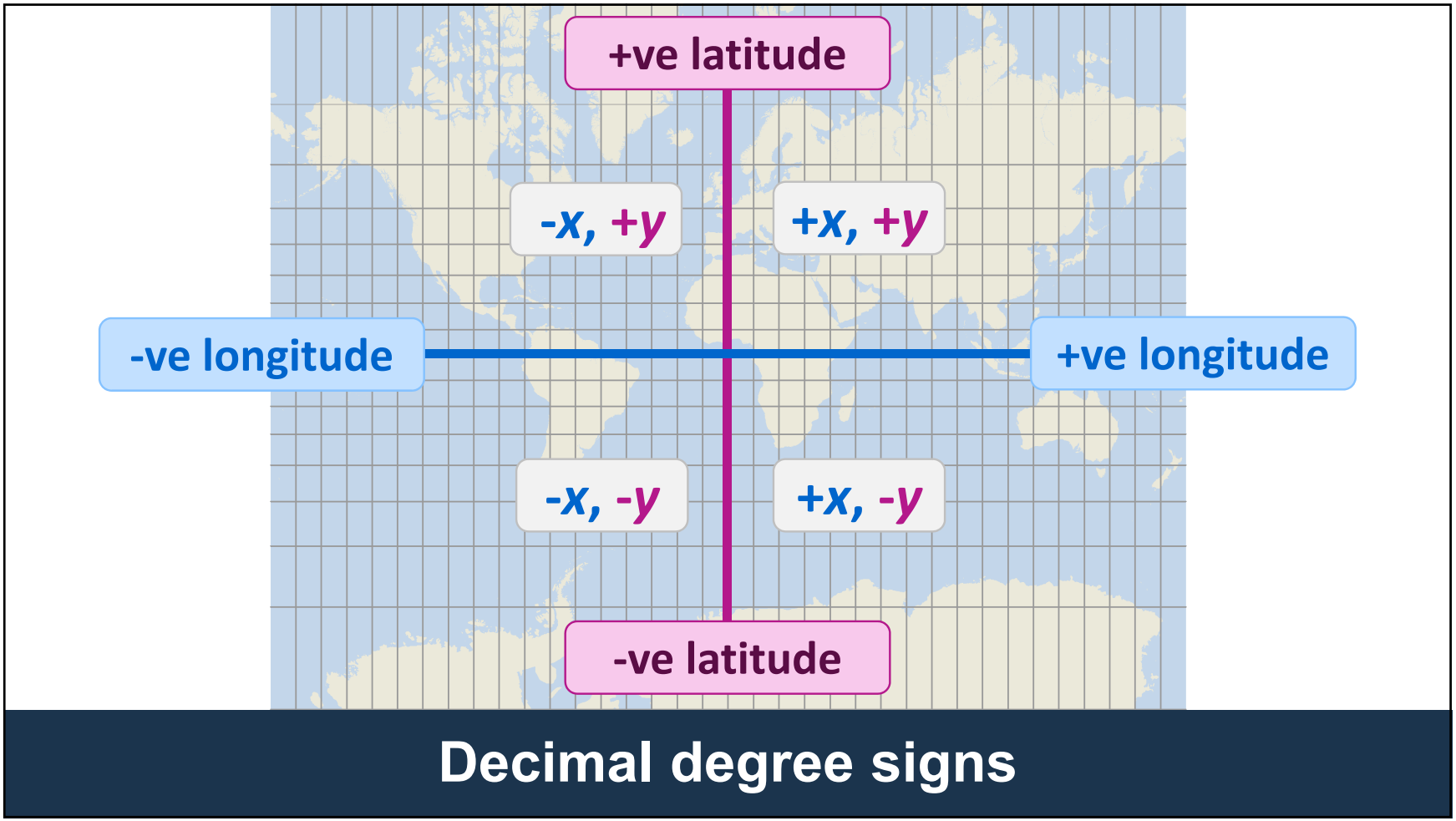
1 minute = 60 seconds.



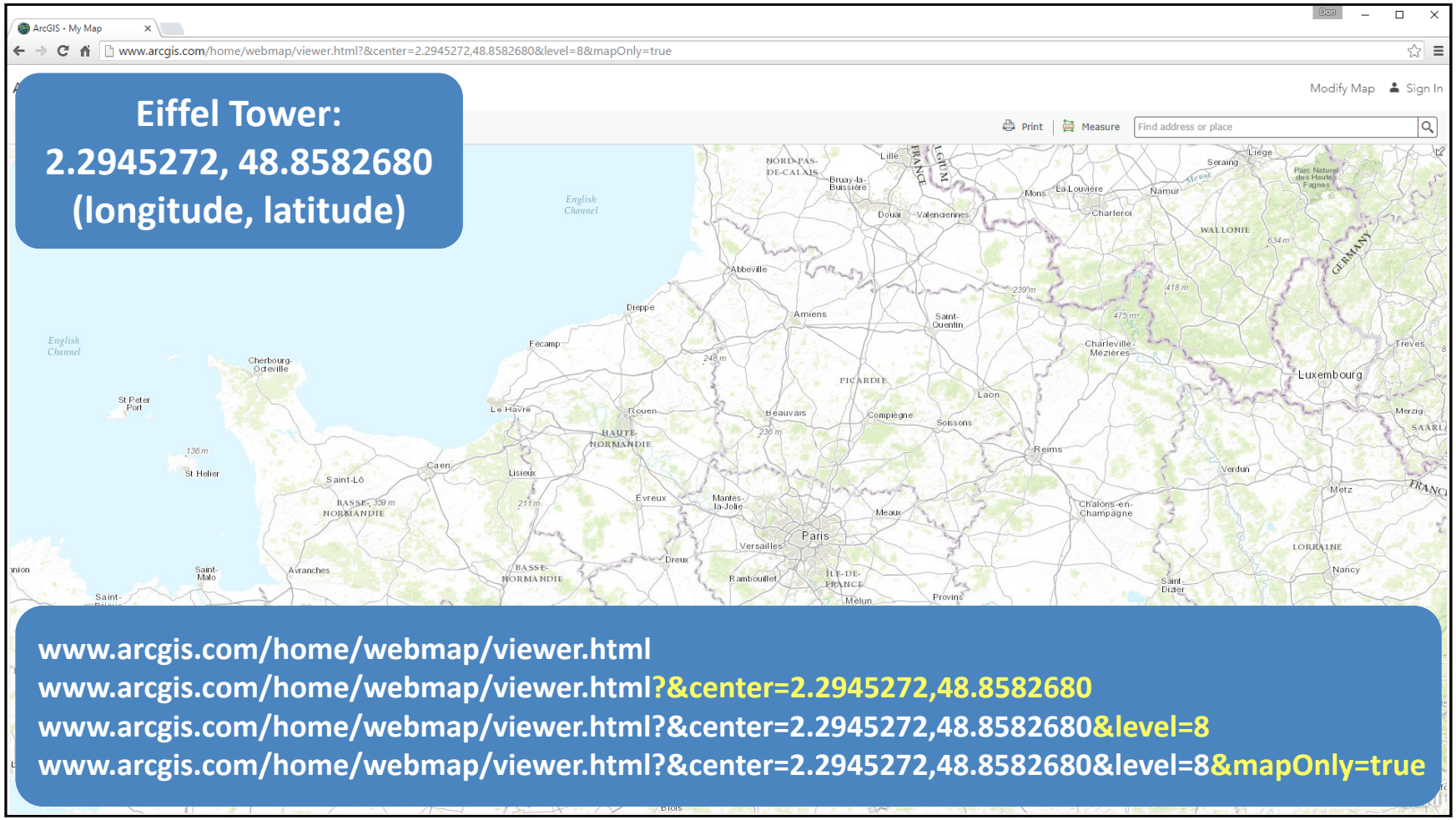
Recording coordinates



Recording coordinates



Decimal degree signs



121° 8’ 6”

Converting DMS/DD coordinates

= 121 + (8/60) + (6/3600)

= 121.135

$$121° 8' 6''$$

$$= D + (M/60) + (S/3600)$$

$$= 121 + (8/60) + (6/3600)$$

$$= 121.135$$

Degrees, Minutes, Seconds → Decimal Degrees

121°.135

.135 x 60 = 8.1

.1 x 60 = 6

121° 8’ 6”

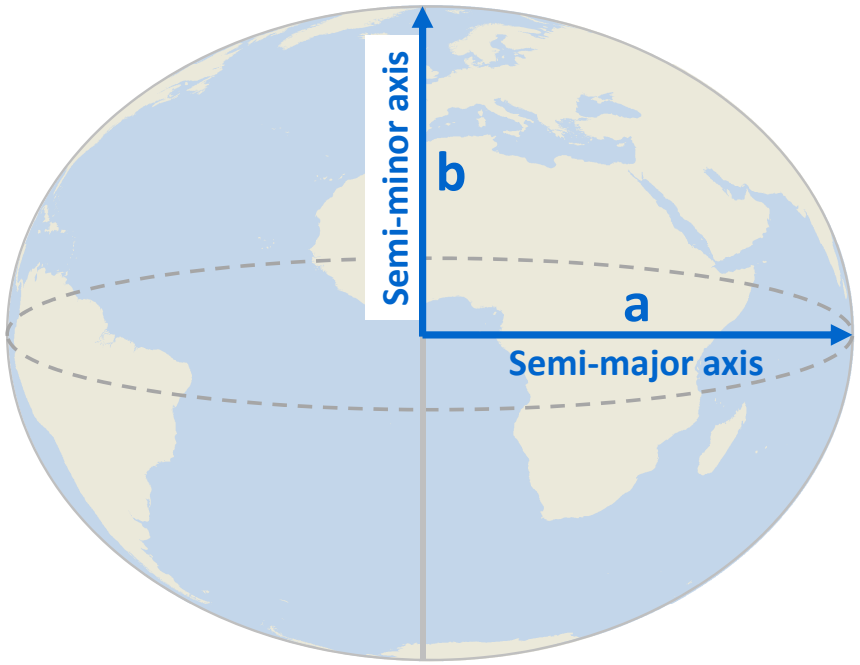
Decimal degrees → Degrees, minutes, seconds

The Earth as an Ellipsoid

$$f \approx \frac{1}{300}$$

The earth is not round

Flattening and bulging



$$f = \frac{a-b}{a}$$

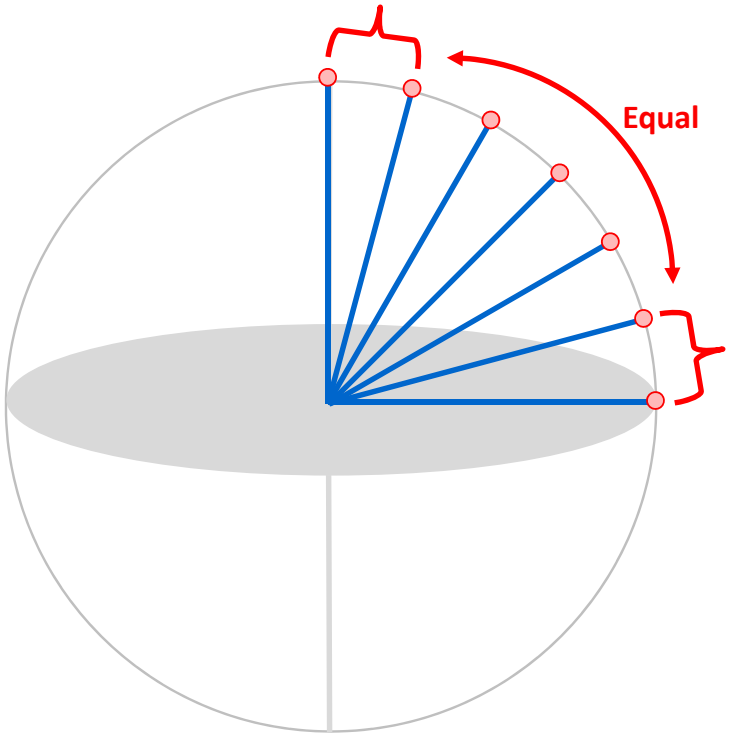
$$f \approx \frac{1}{300}$$

Earth can be modeled as an ellipsoid

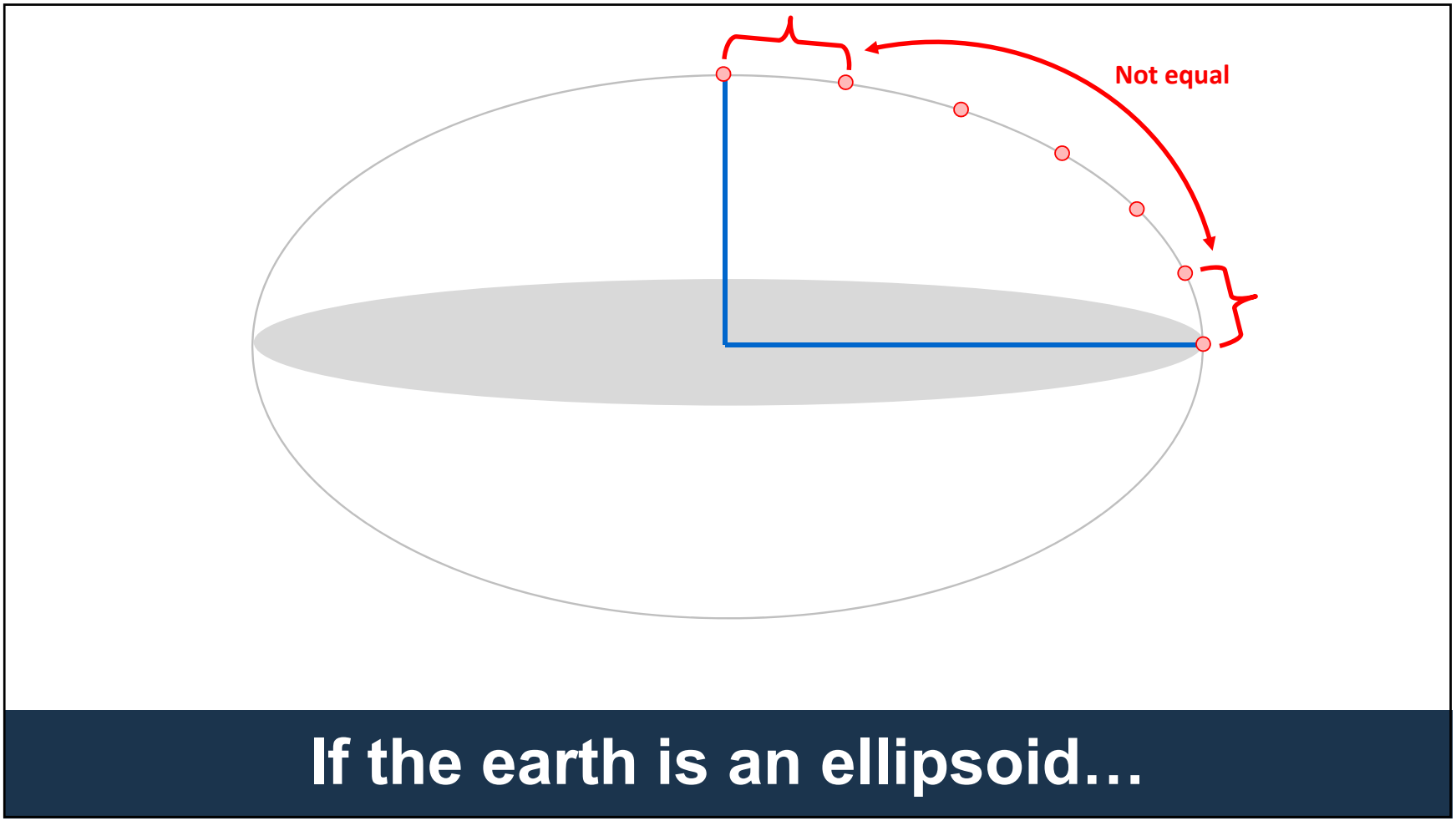
Ellipsoid Examples

Ellipsoid	Semi-major axis (m)	Flattening (1/f)
Airy 1830	6,377,563.396	299.3249646
Australian National	6,377,340.189	298.25
Clarke 1866	6,378,206.4	294.9786982
International 1924	6,378,388	297
GRS 80	6,378,137	298.257222101

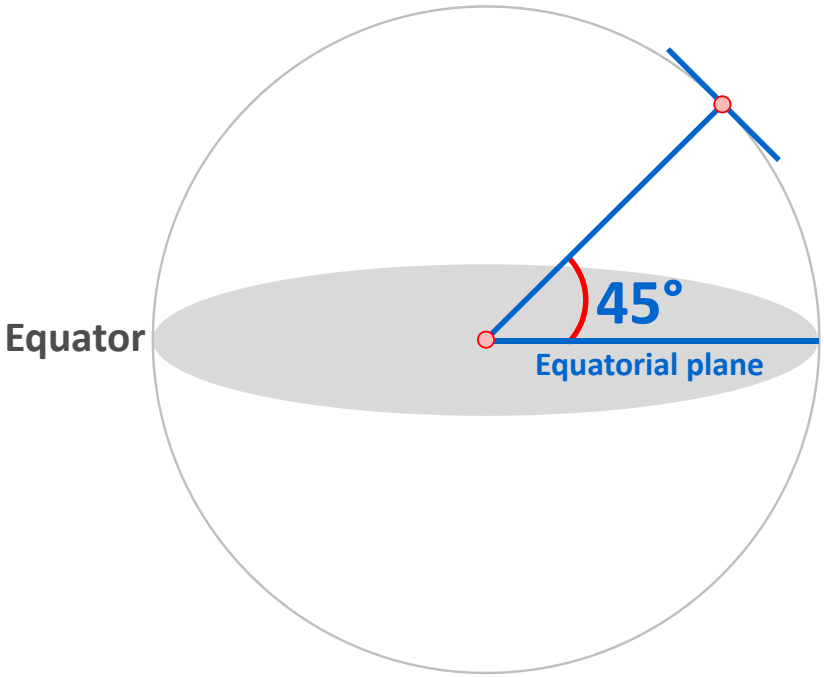
(adapted from Lo and Yeung, 2006)



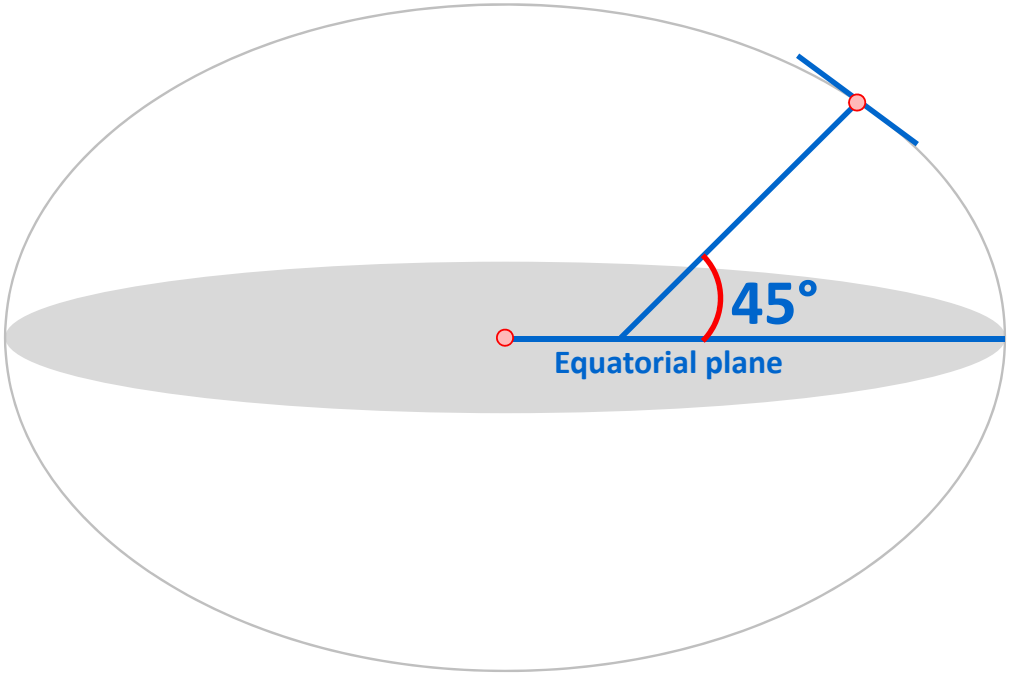
If the earth was a sphere…



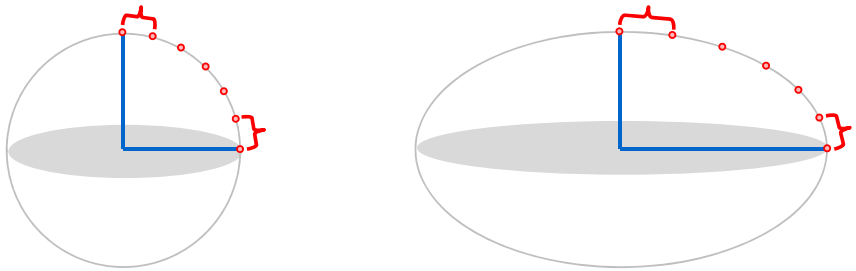
If the earth is an ellipsoid…



Geocentric latitude



Geodetic latitude



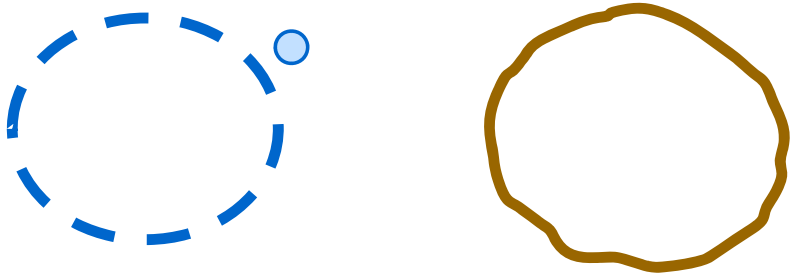
- If you treat the Earth as a sphere to measure distance you will be off by about 1 km for every 110 km (~1%)
- 1:5 million or smaller: not noticeable, use **geocentric**
- 1:1 million or larger: noticeable, use **geodetic**.

Distance measurements

Horizontal datum

Ellipsoids

- Each ellipsoid is designed to approximate the Earth's shape for one part of the planet
- How do we specify *which part*?
  - Use a datum.

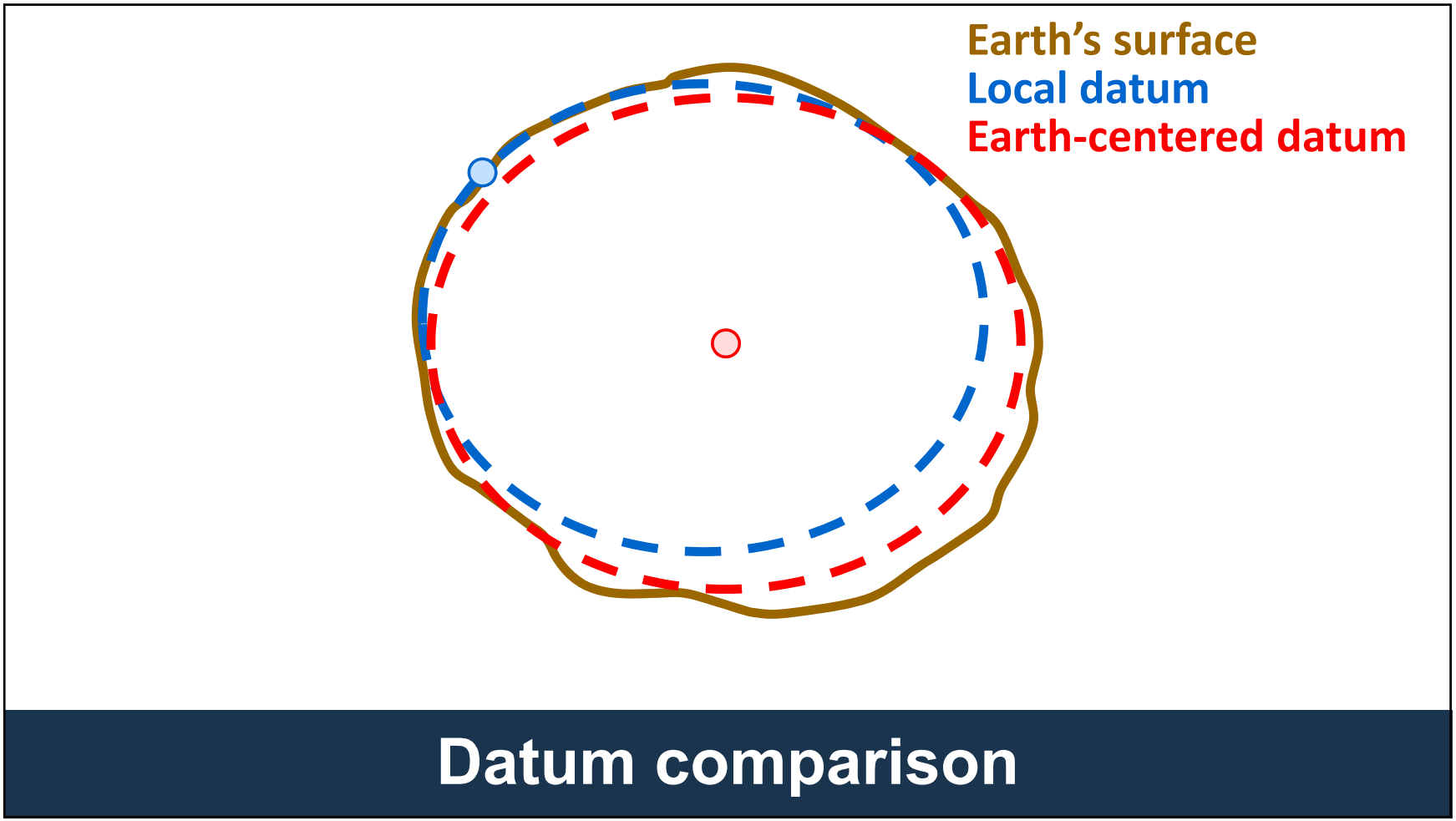


Ellipsoid **Earth**

Specifies ellipsoid used and its location

point on ellipsoid linked to point on earth
(the origin, from which all other points are calculated).

Datum



Datum comparison

Datums

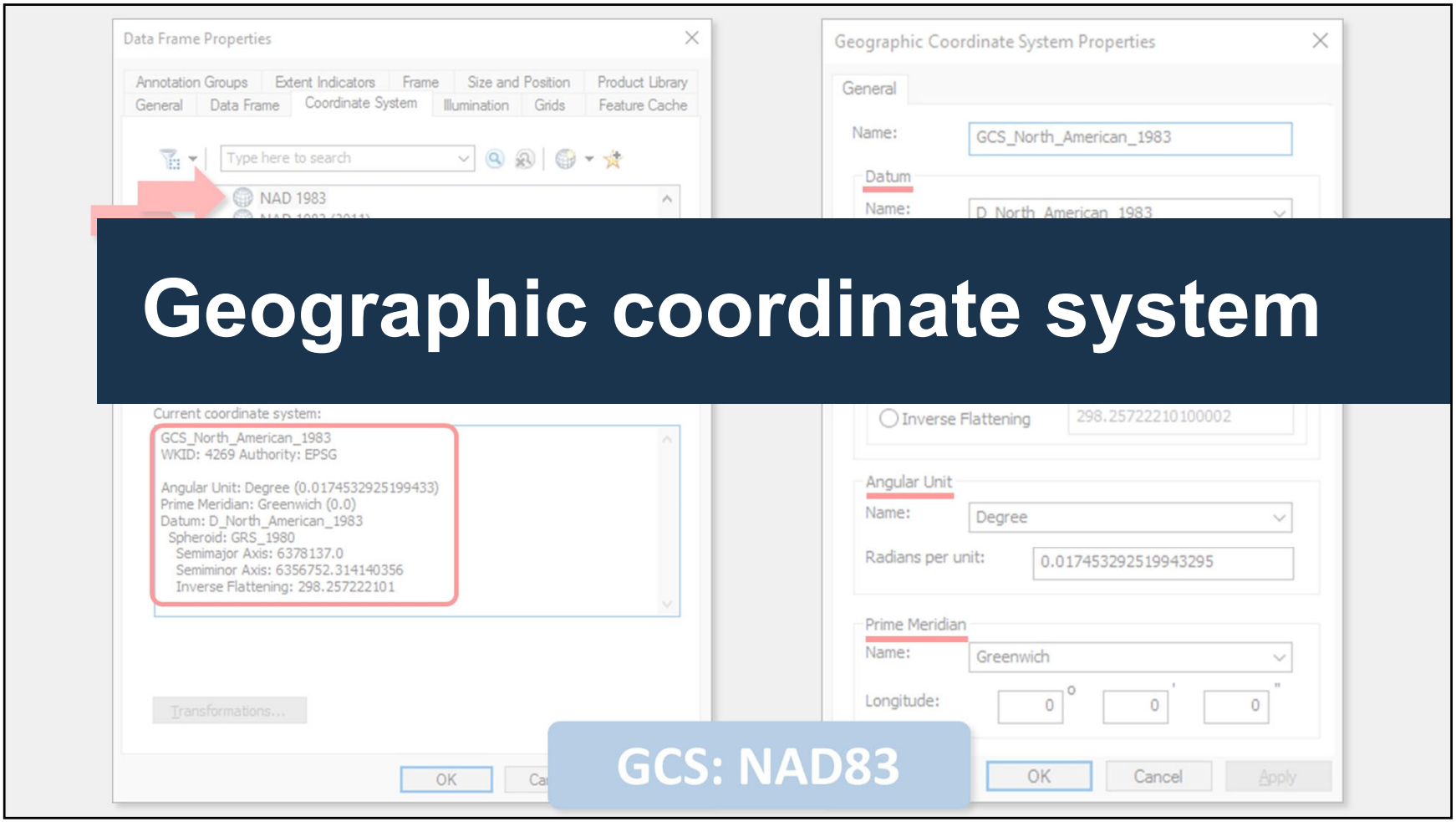
- Hundreds of different ellipsoids and datums have been used since the first estimates of the earth's size were made by Aristotle

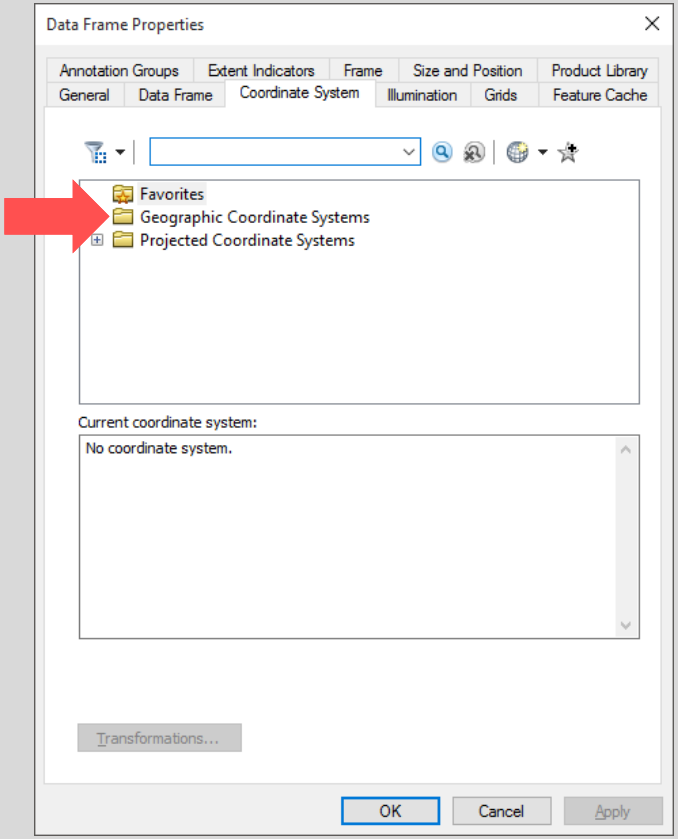
Datum Elements	NAD 27	NAD 83
Ellipsoid	Clarke 1866	GRS 80
Semi-major axis	6,378,206.4 m	6,378,137.0 m
Datum origin	Meades Ranch, Kansas	Center of Earth's mass
Control points	25,000	250,000
Best fitting	North America	Worldwide

(adapted from Lo and Yeung, 2006)

NAD 27 vs. NAD 83

Meades Ranch, Kansas

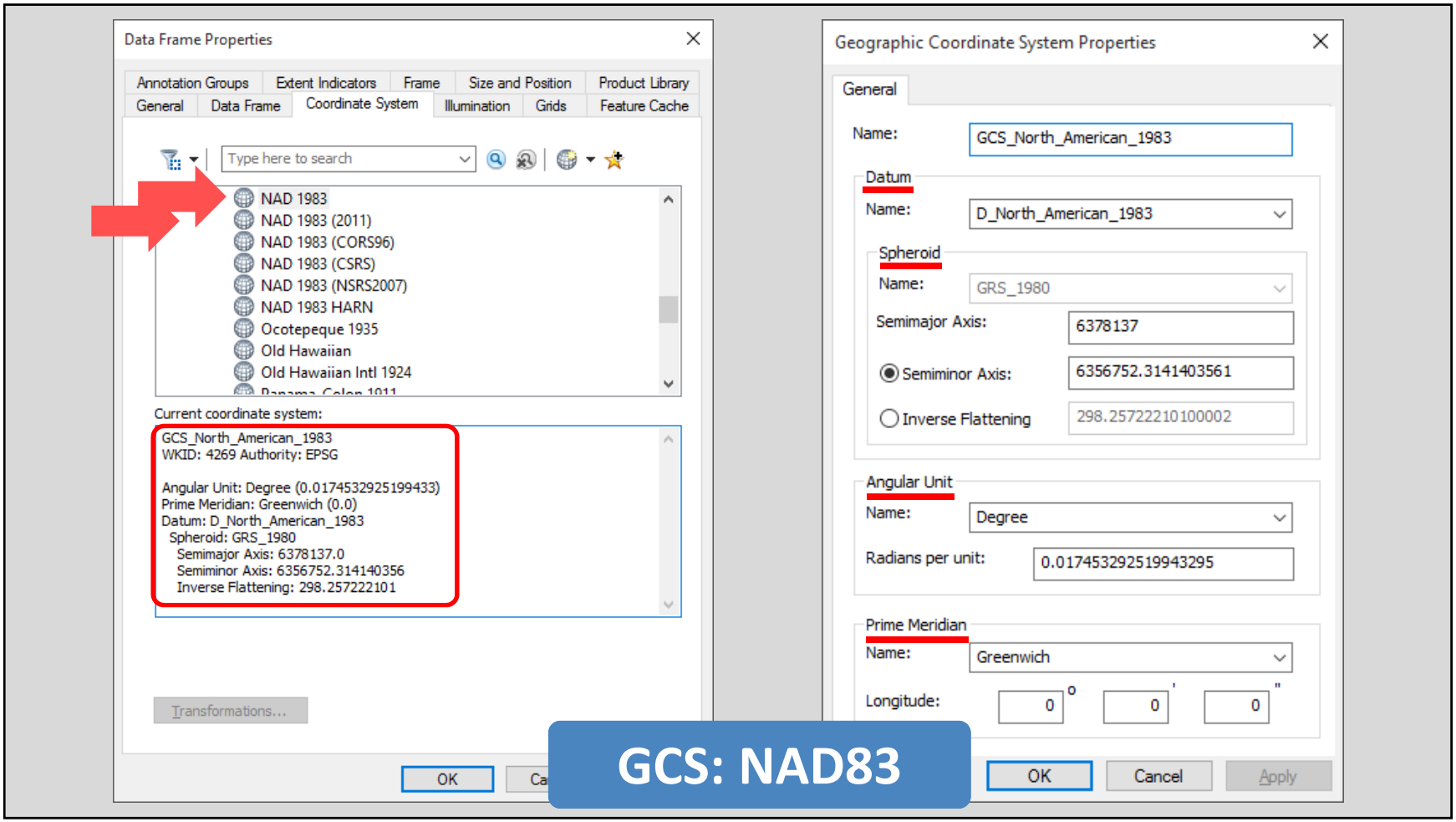




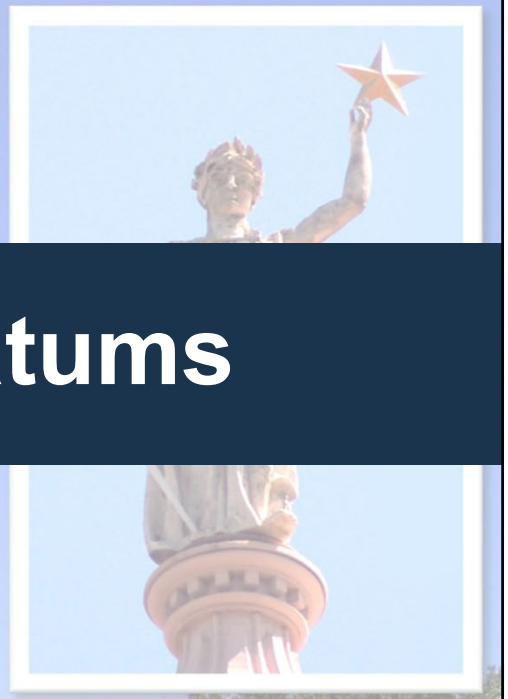
Selecting a coordinate system

Geographic Coordinate System

- Consists of:
  - Angular unit of measure
  - Prime meridian
  - Datum
    - Specifies an ellipsoid
- There are many different ellipsoids, so there are many different geographic coordinate systems.



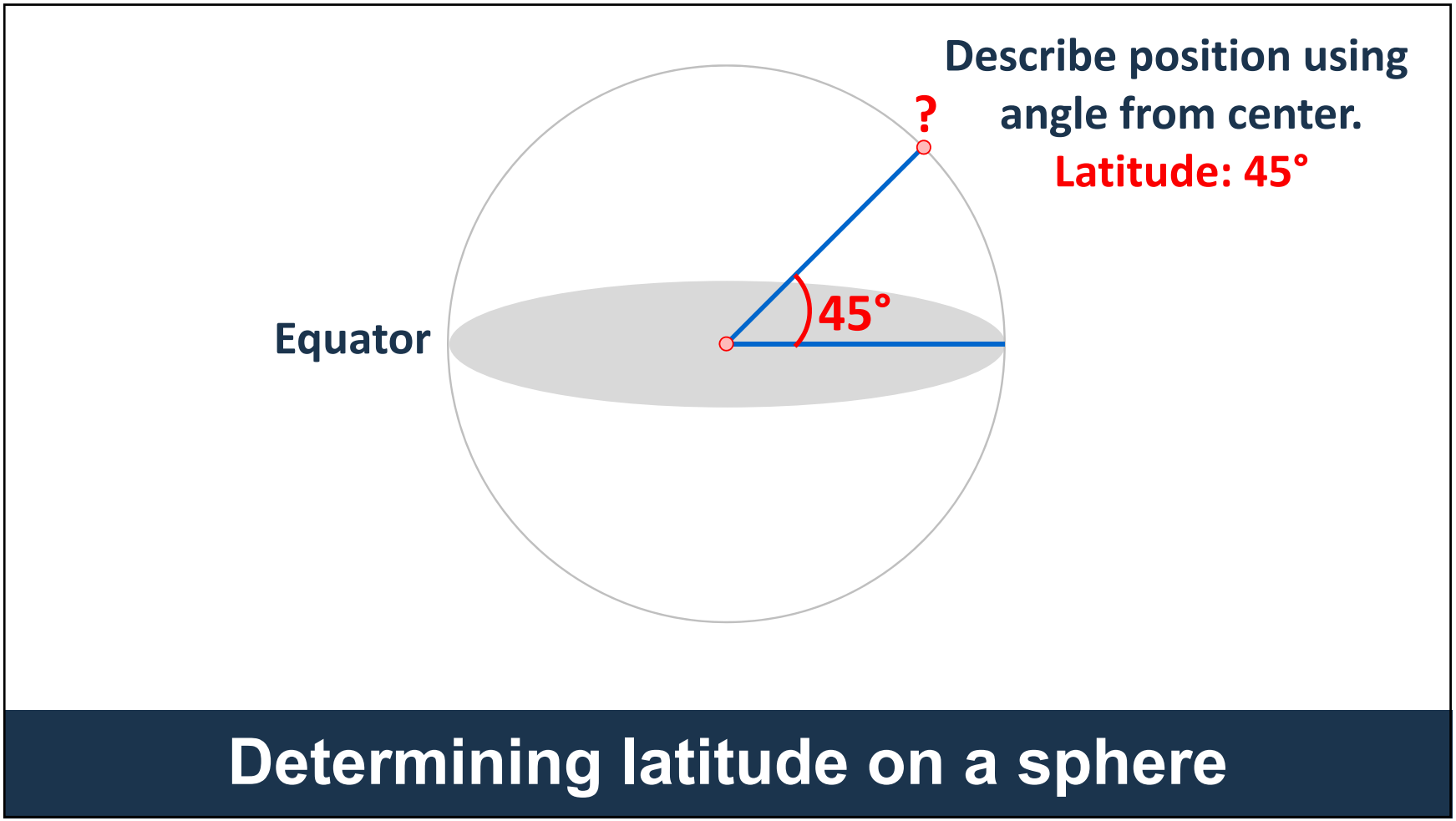
Changing horizontal datums



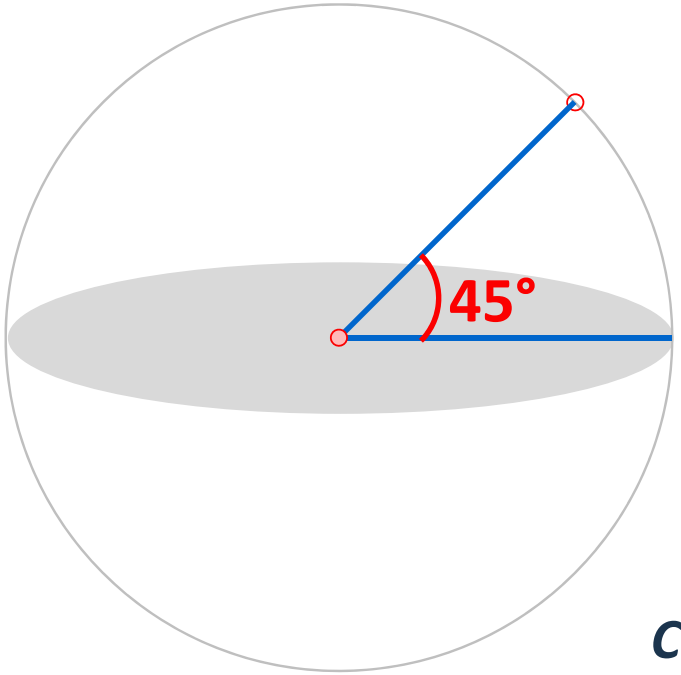
Goddess of Liberty

Changing datums

- Geographic coordinate system
  - Angular unit of measure
  - Prime meridian
  - Datum
    - Based on an ellipsoid
- Since the datum is part of the definition, if you change the datum, you are changing the geographic coordinate system, so your coordinates will change.



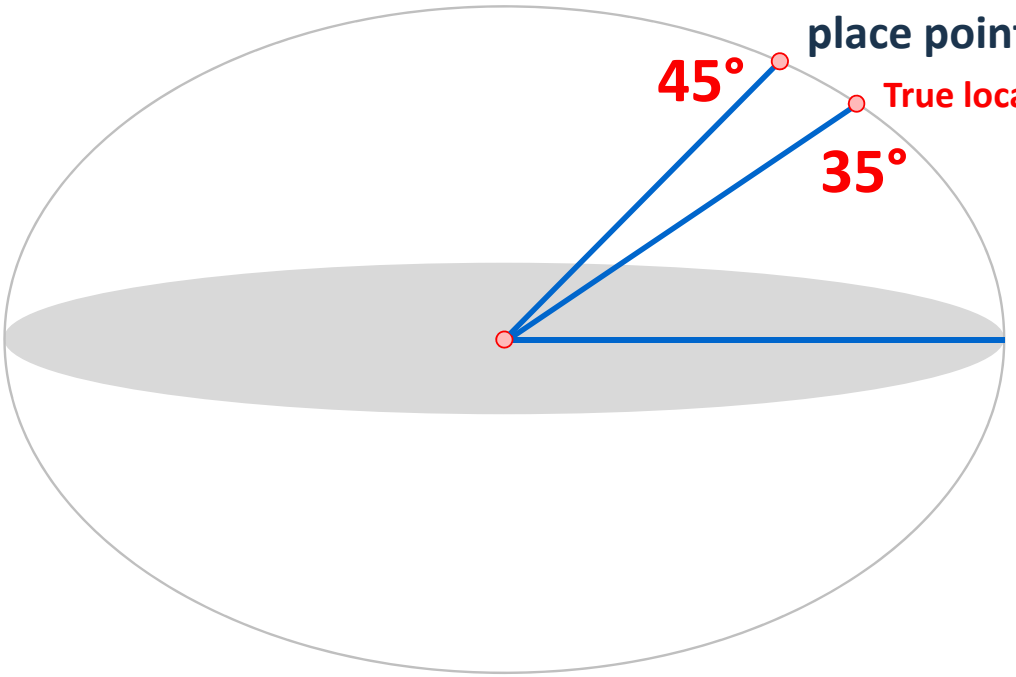
Determining latitude on a sphere



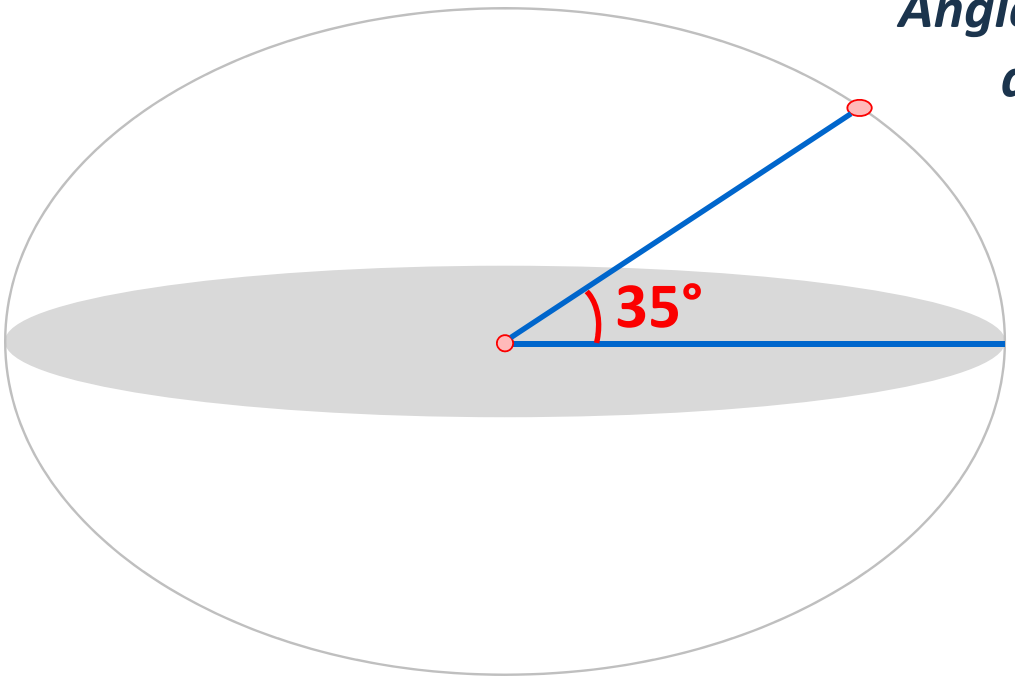
Point is no longer at 45° latitude

Changing the shape also changes the angle

If sphere changes to an ellipsoid…



Put another way…



Changing ellipsoids

Geographic coordinates

- The datum (and, therefore, the ellipsoid) is the frame of reference for the coordinates
- When you map angular coordinates, you must use the same datum that was used to originally measure them.

In other words…

- The same location will have different coordinates on a sphere vs. an ellipsoid, and also on different ellipsoids

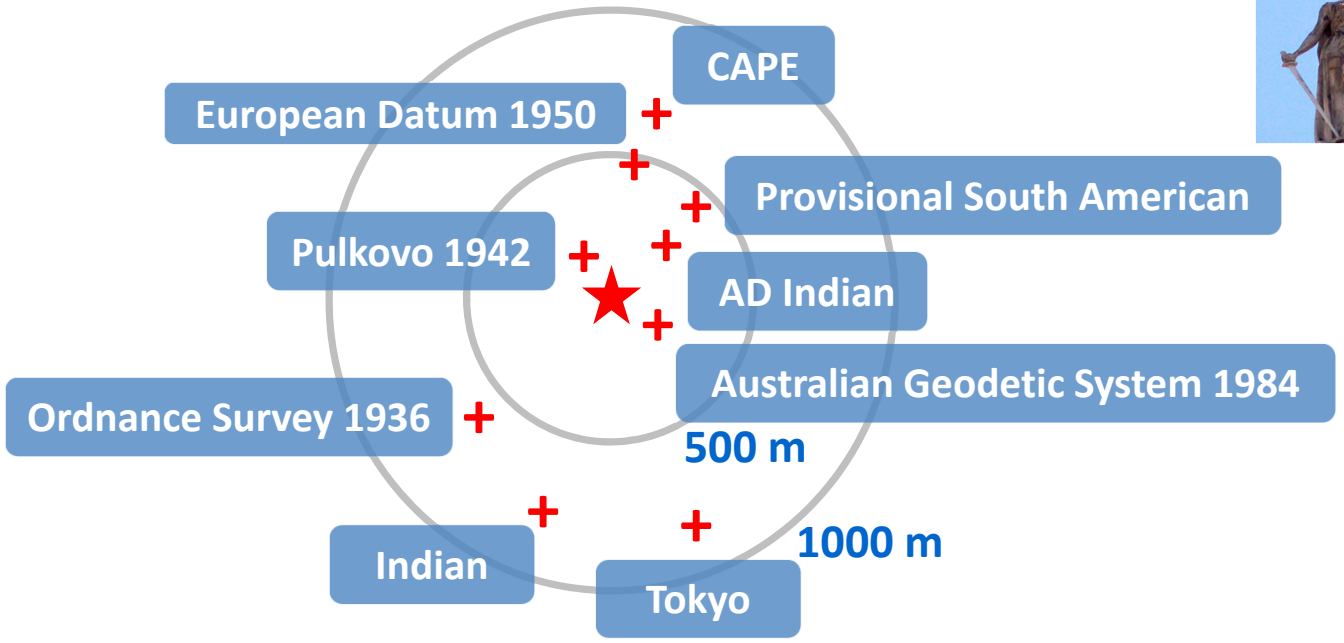
Changing datums

Same point in Redlands, California:

NAD 27: -117° 12’ 54.61539” 34° 01’ 43.72995”

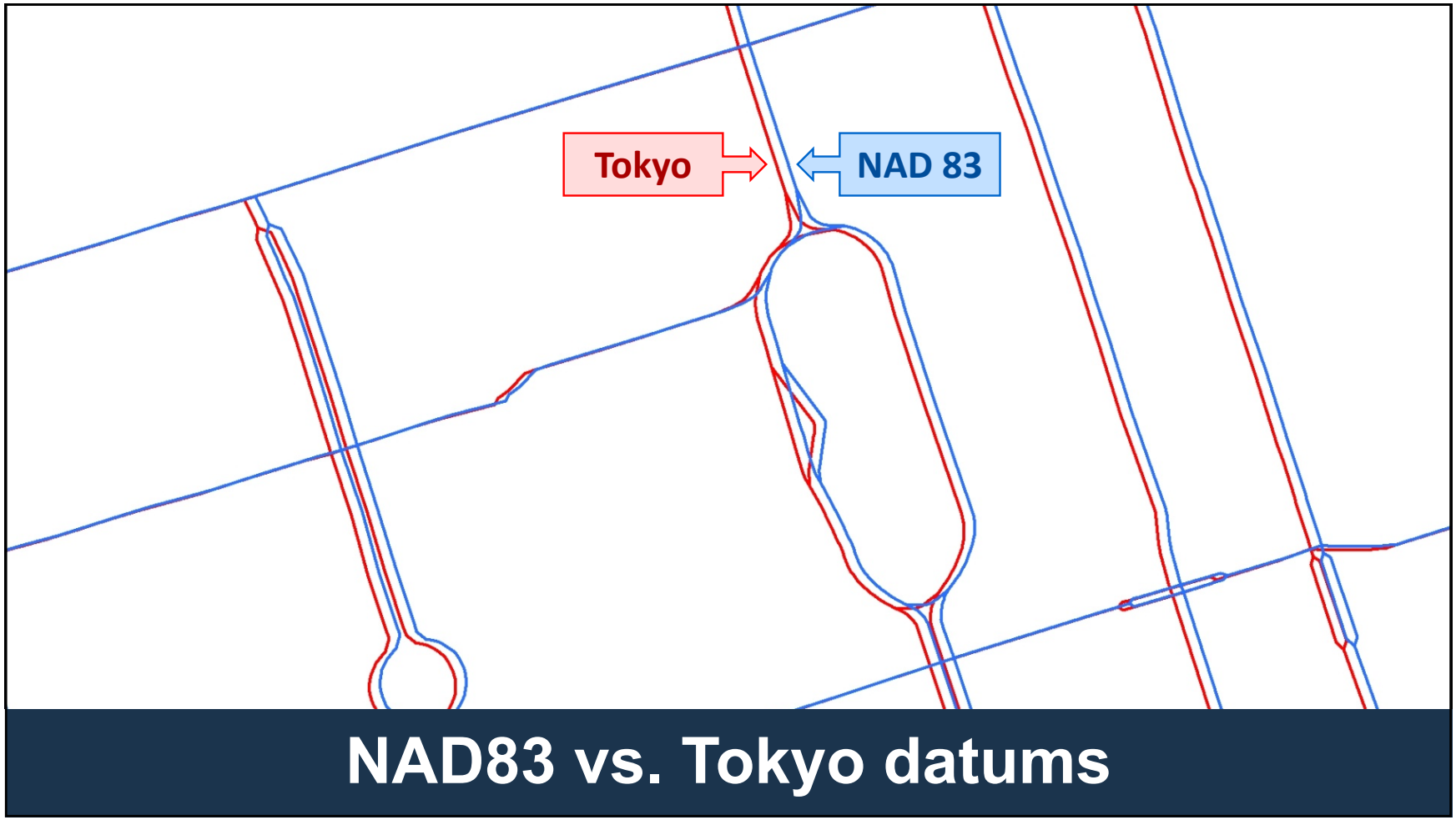
NAD 83: -117° 12’ 57.75961” 34° 01’ 43.77884

Texas State Capitol Building, Austin

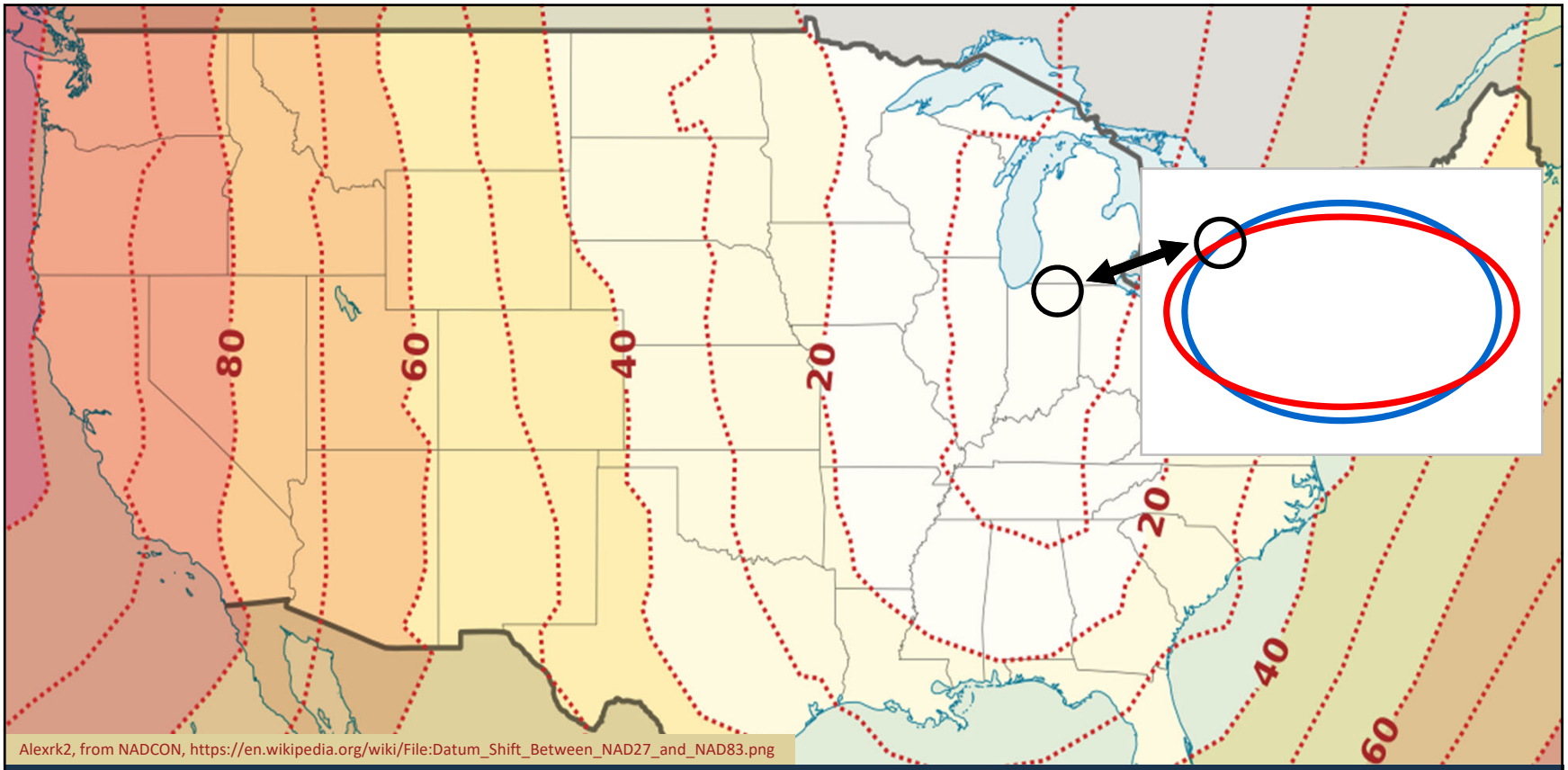


http://www.colorado.edu/geography/gcraft/notes/datum/datum.html

Datum differences



NAD83 vs. Tokyo datums

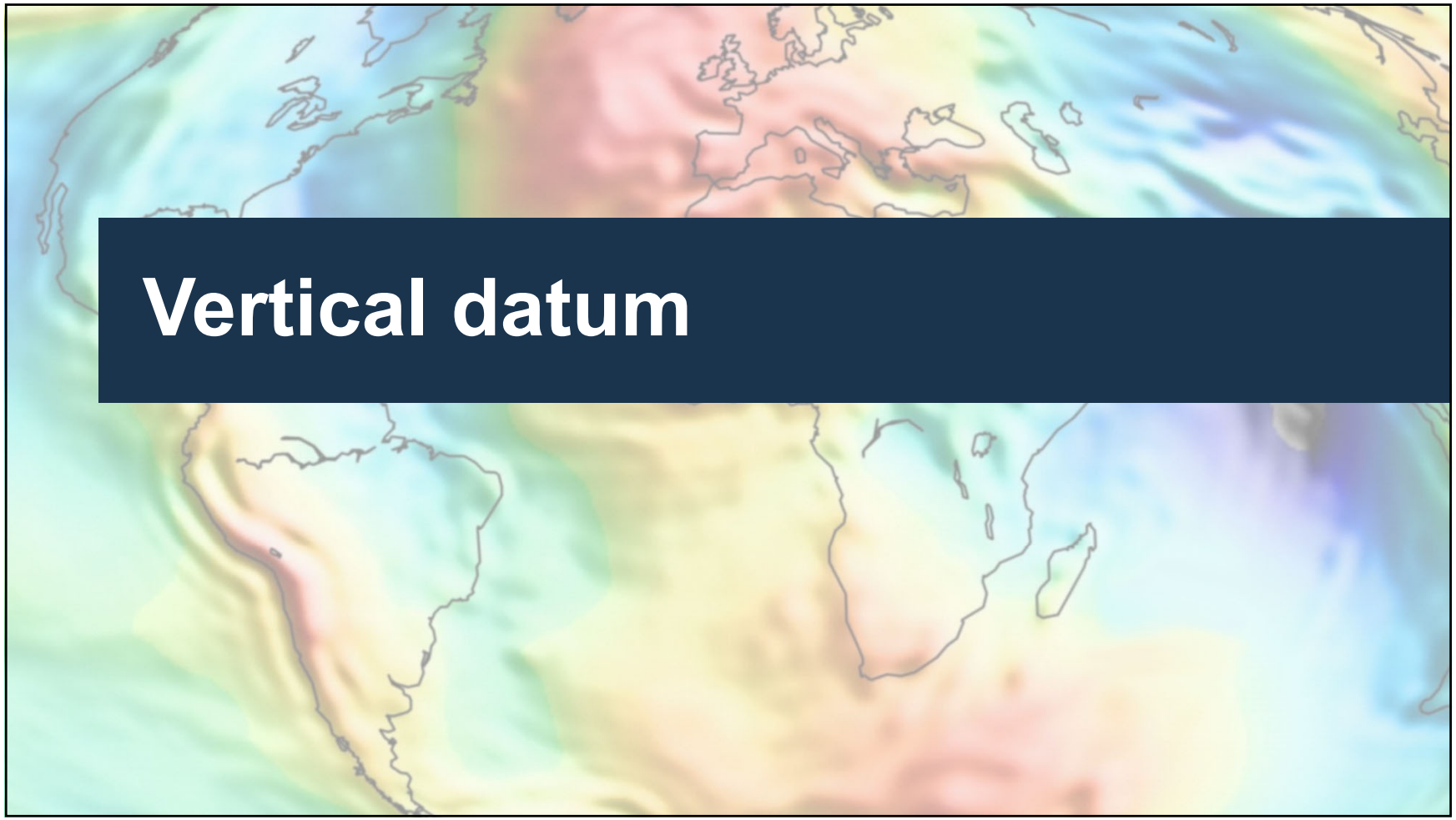


Alexrk2, from NADCON, https://en.wikipedia.org/wiki/File:Datum_Shift_Between_NAD27_and_NAD83.png

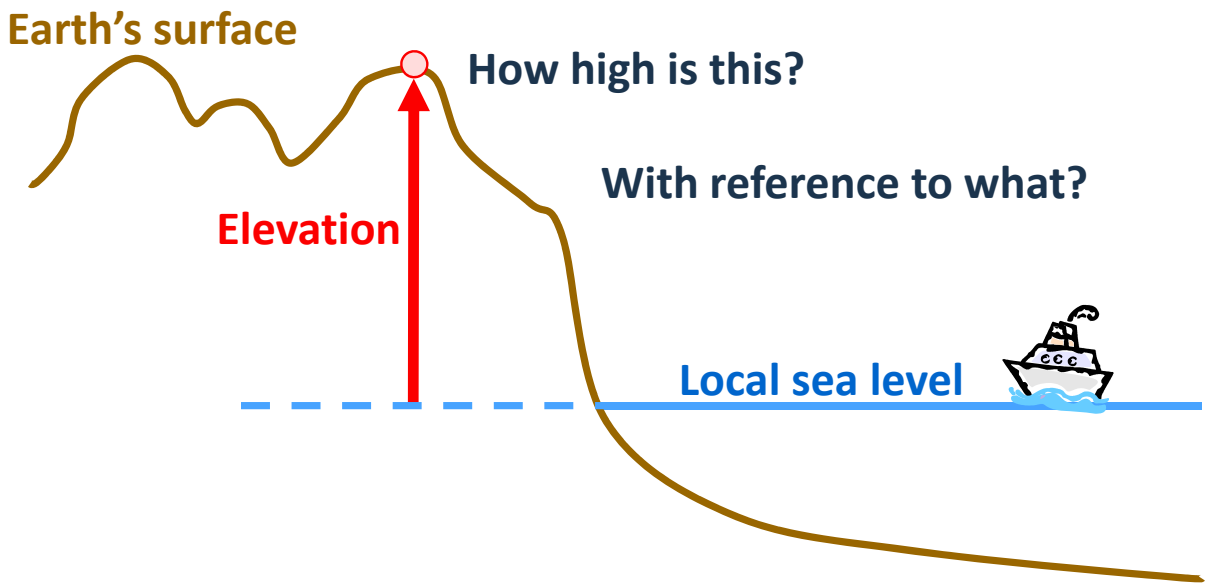
Difference (m) of same coordinates in NAD 27 vs NAD 83

Datums and GIS

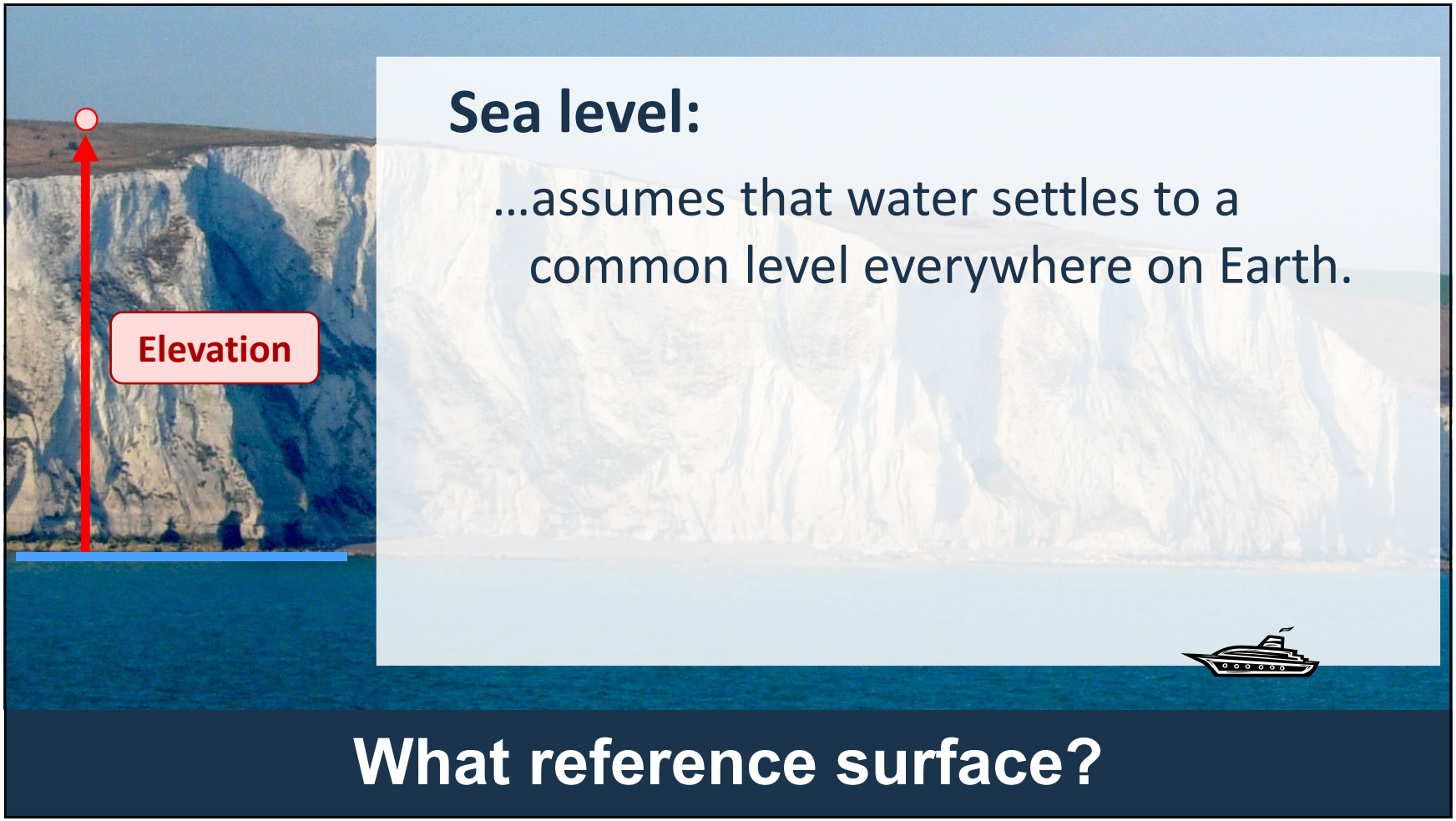
- Data acquisition
  - must know datum used to create data
  - if wrong one used, will have measurement errors, objects may not line up properly

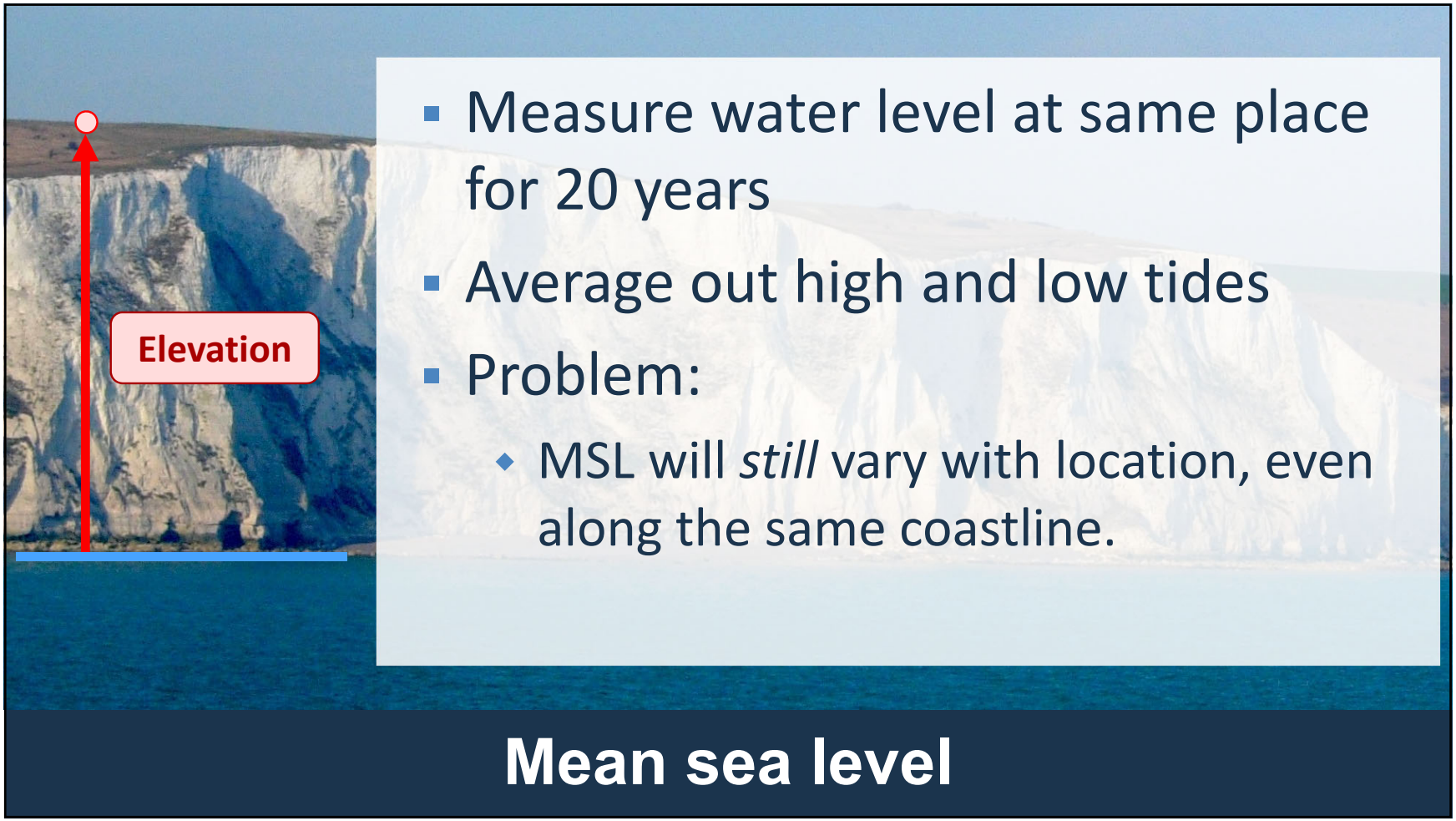


Vertical datum



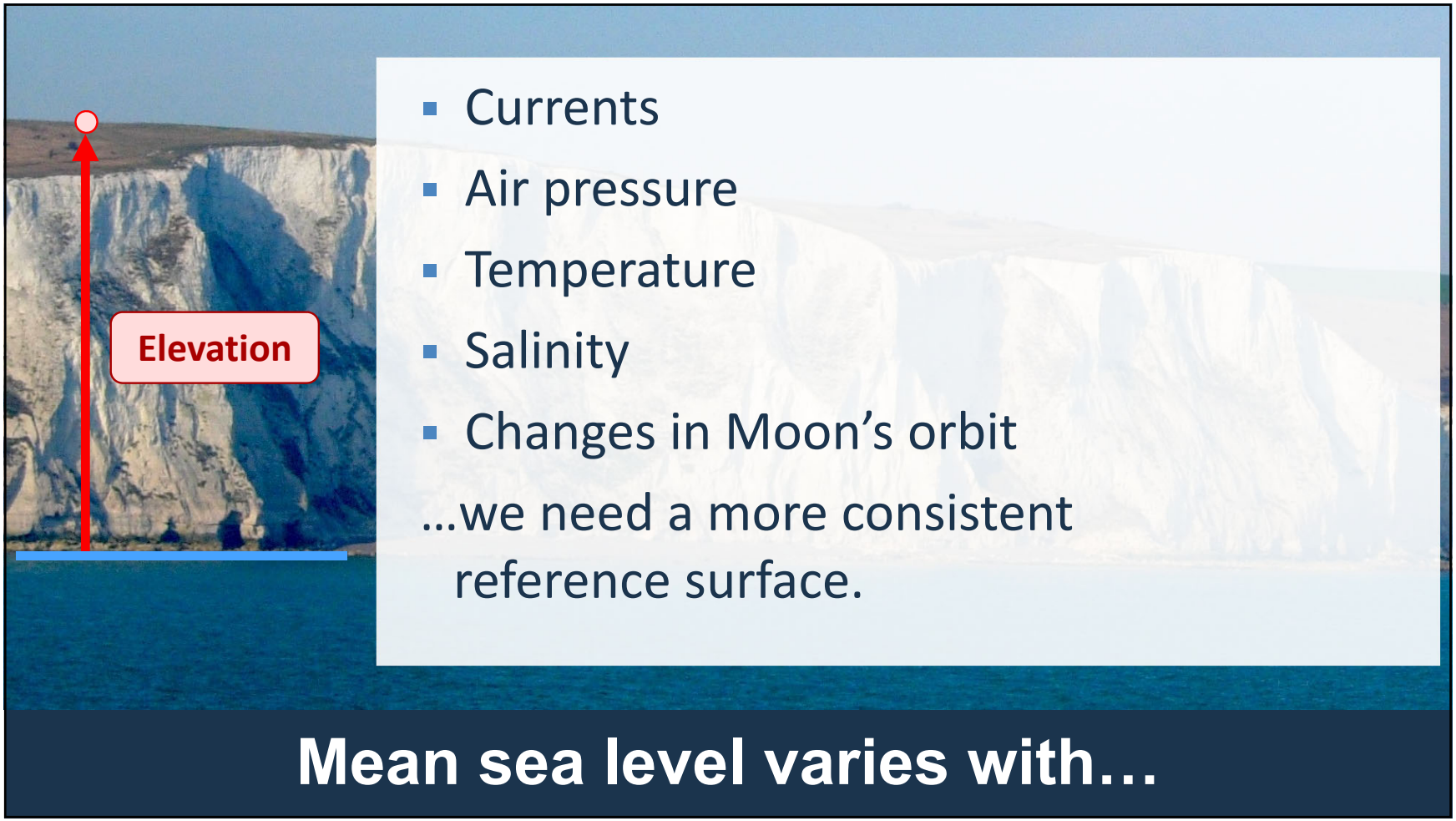
Vertical Position

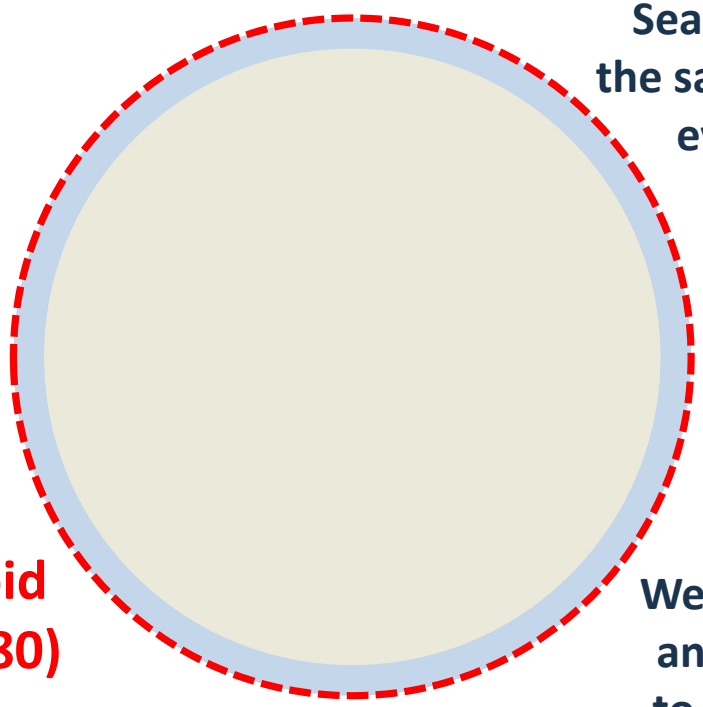




- Measure water level at same place for 20 years
- Average out high and low tides
- Problem:
  - MSL will *still* vary with location, even along the same coastline.

Mean sea level





Sea level would be
the same everywhere,
even over land

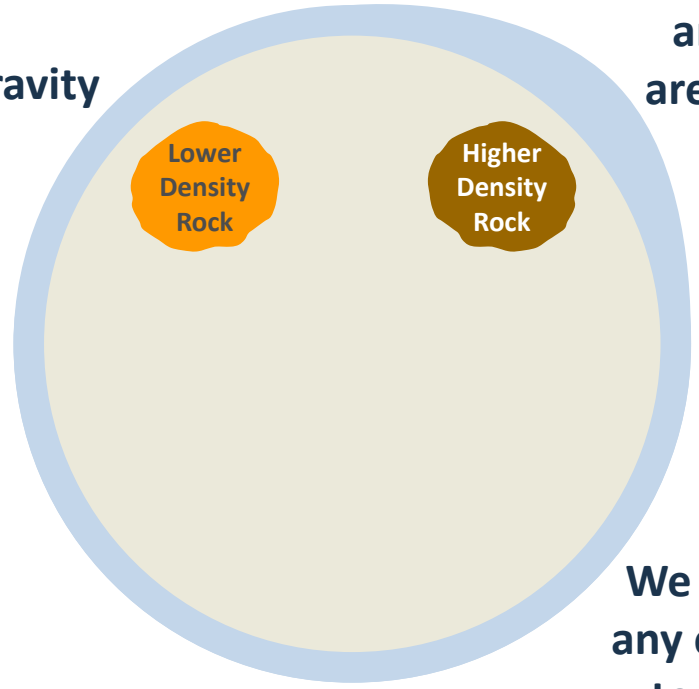
Ellipsoid
(GRS80)

We could then measure
any elevation relative
to this one “sea level”

If water could settle to one level…

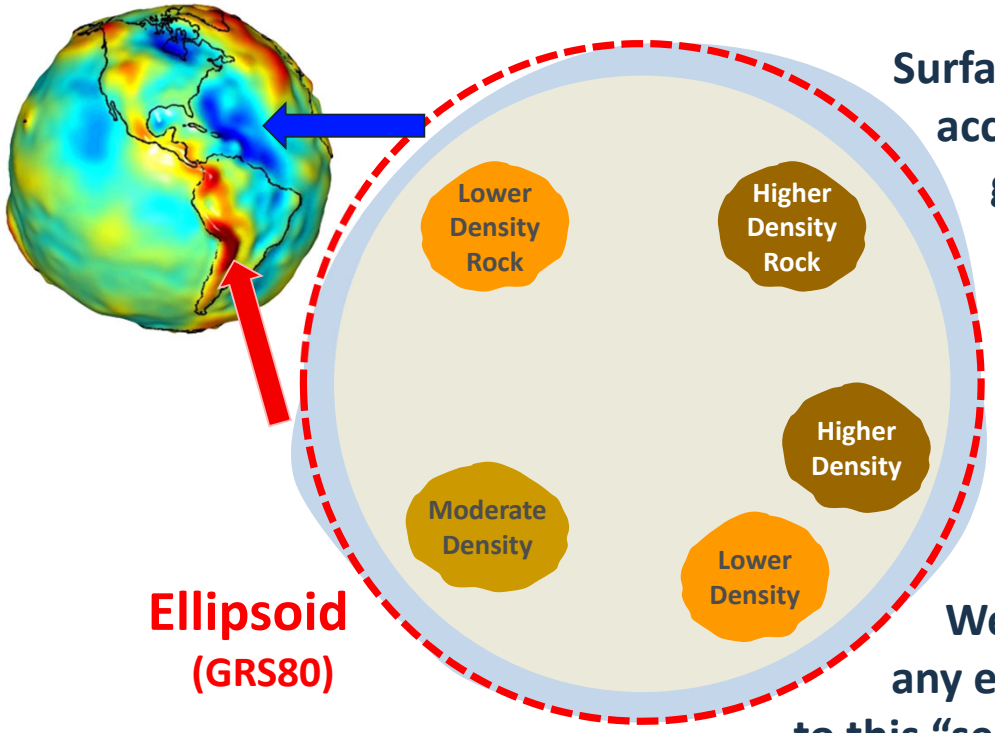
Water is drawn
away from
areas of lower gravity

Water collects
and “bulges” above
areas of higher gravity



We can still measure
any elevation relative
to this “sea level”

If we account for gravity…

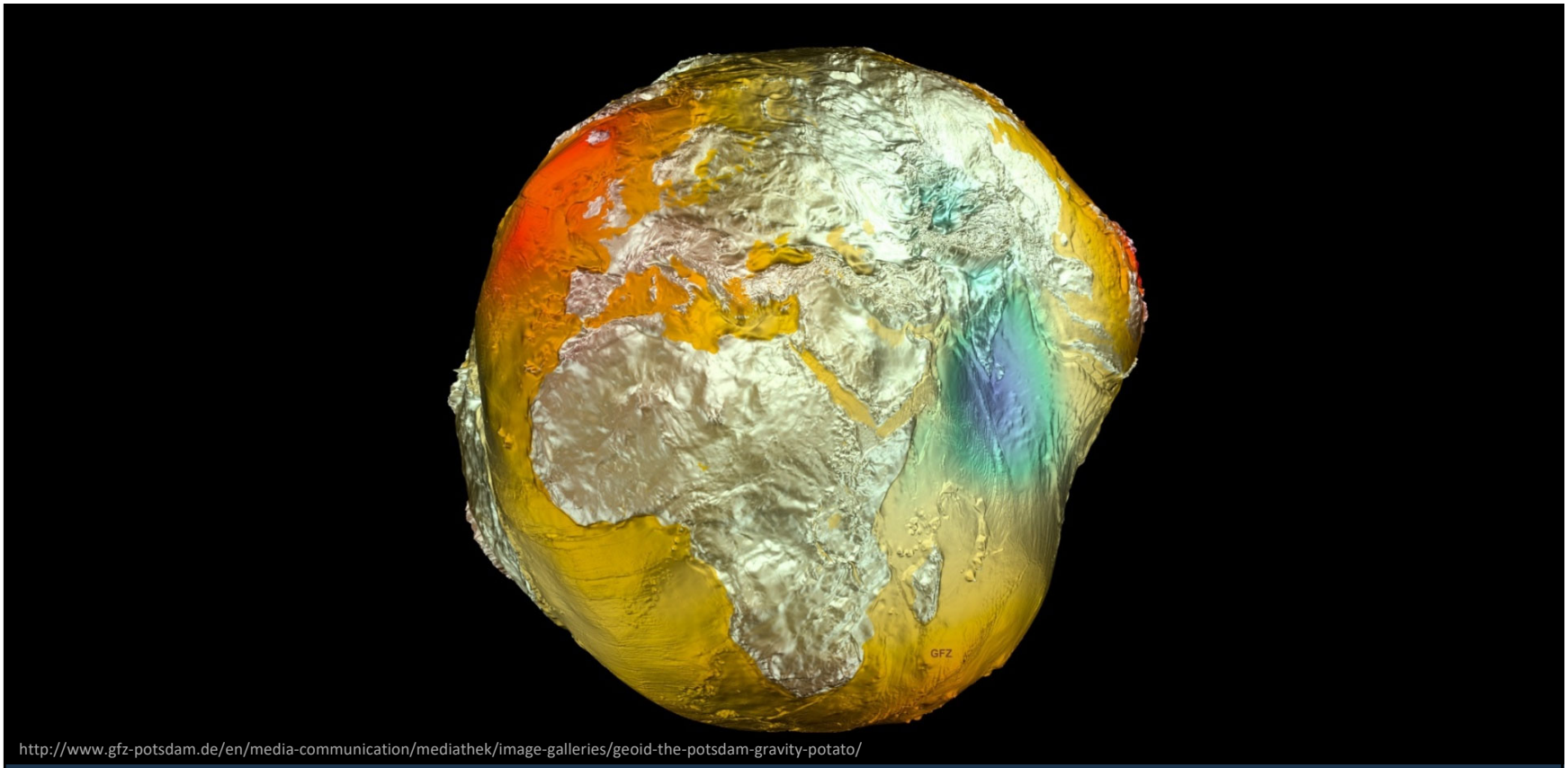


Surface undulates according to gravitational pull

Ellipsoid
(GRS80)

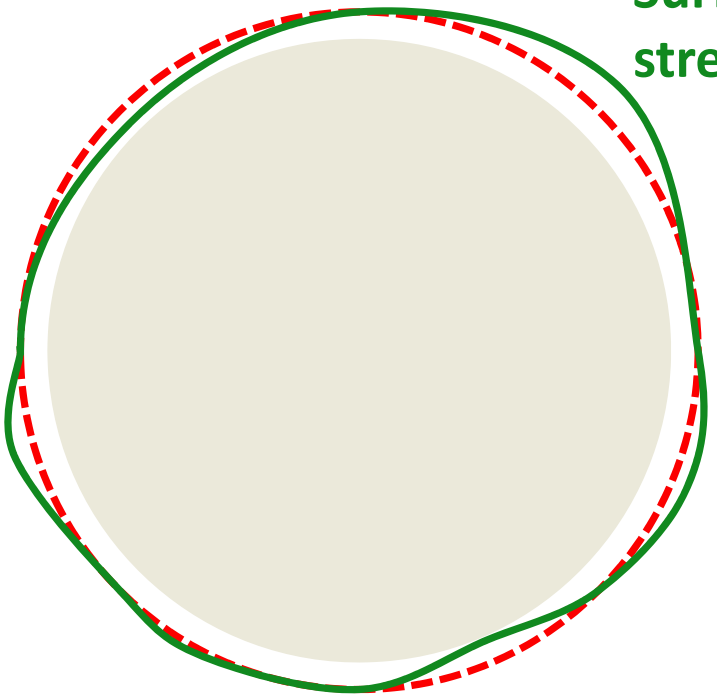
We can <u>still</u> measure any elevation relative to this "sea level" called the geoid

If we account for gravity…

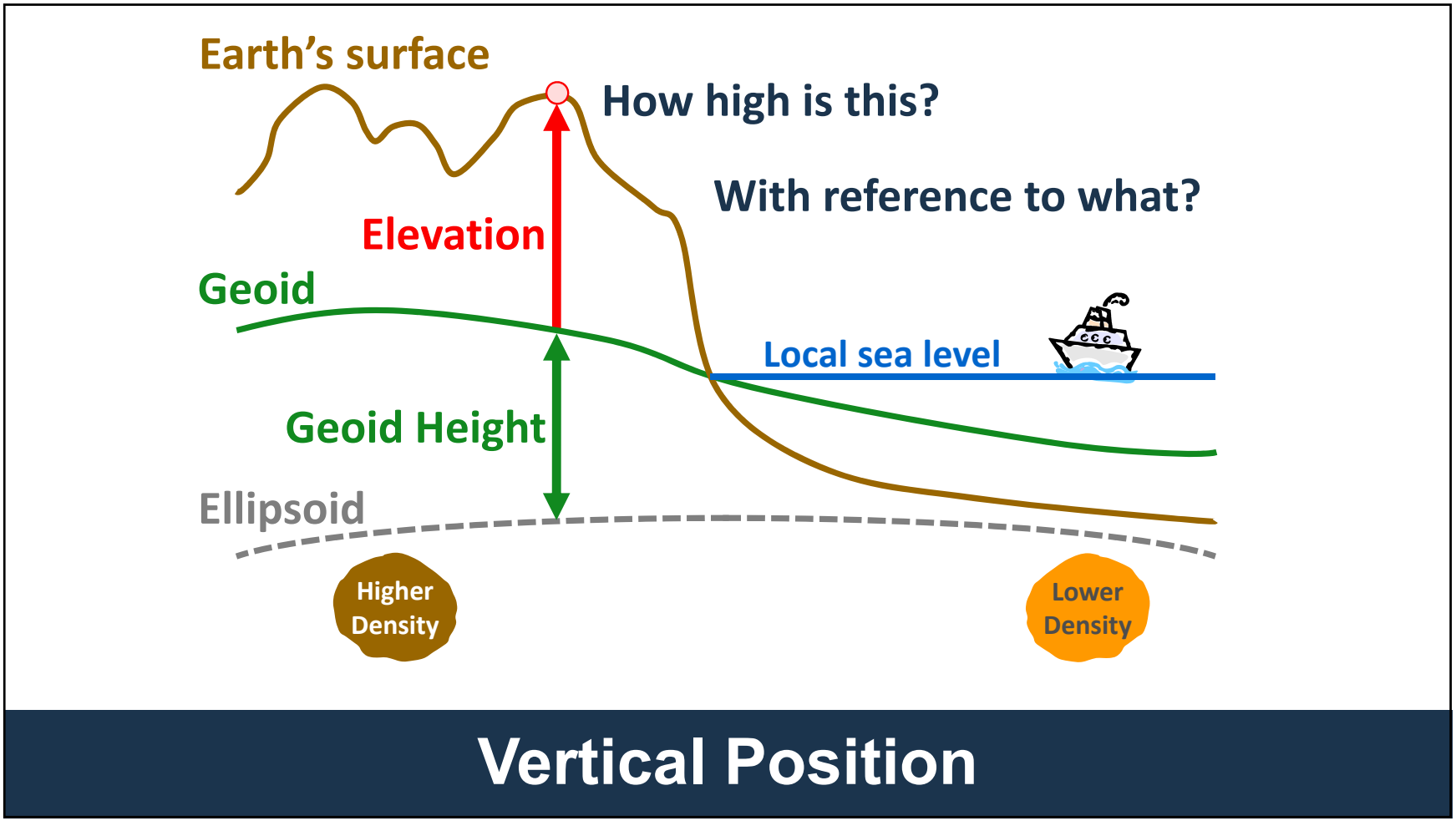


http://www.gfz-potsdam.de/en/media-communication/mediathek/image-galleries/geoid-the-potsdam-gravity-potato/

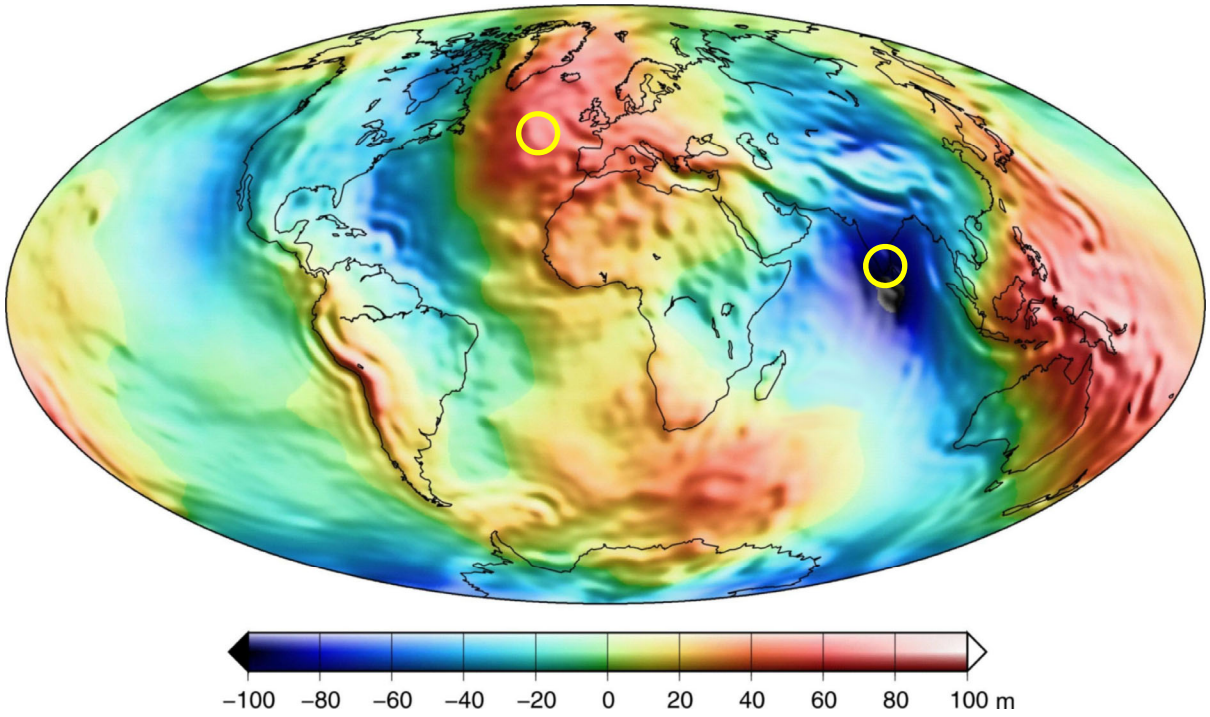
Potsdam gravity potato



Geoid



Vertical Position



http://op.gfz-potsdam.de/grace/results/grav/g002_eigen-grace02s.html

Geoid heights